THE No 1 UK MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EPE EVERYDAY PRACTICAL ELECTRONICS

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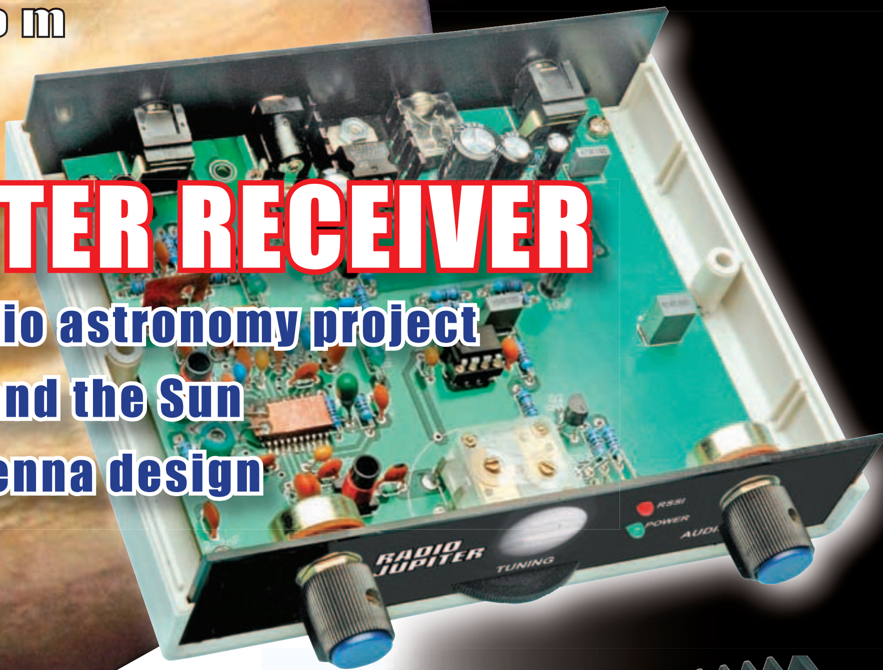

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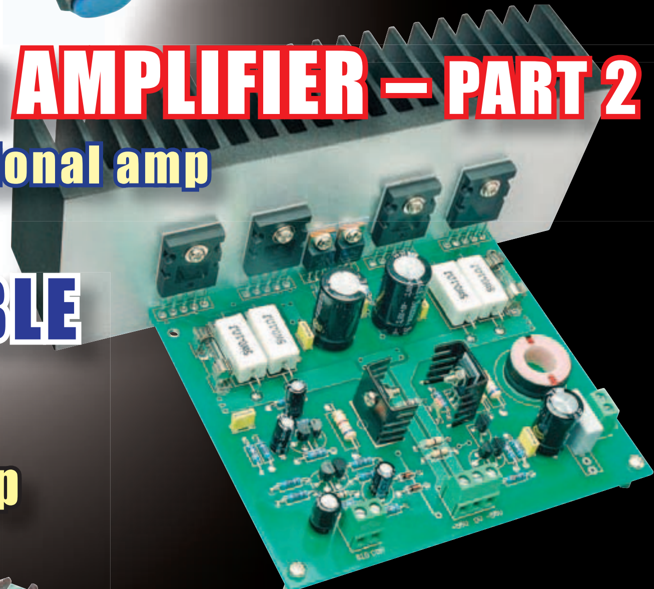

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MK112	Brain Game Minikit	5.95
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VM110	USB Interface Card Module	34.90
VM111	PIC Programmer and Experiment Module	32.60
VM112	Personal Animated Badge Module	19.95
VM113	Stereo Amplifier Module 2 x 30W	19.25
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VM116	USB Controlled DMX Interface Module	67.15
VM118	8-Channel RF Remote Control Set Module	68.77
VM118R	8-Channel RF Remote Transmitter Module	36.02
VM119	One Channel Dual Output Receiver	19.40
VM120	10-Channel Light Effect Generator	32.02
VM121	15-Channel Infrared Transmitter Module	36.02
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VM125	Ultrasonic Radar Module	26.54
VM129	8-Channel Relay Card Module	33.29
VM130	2-Channel RF Remote Control Set Module	35.45
VM130T	2-Channel RF Remote Control Transmitter	12.90
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VM132	Universal Temperature Sensor Module	13.04
VM133	Energy Saver Module	18.15
VM134	PIC Programmer Board Module	36.90
VM135	Magical Dimmer Module	13.58
VM136	Interval Timer Module	6.30
VM137	Thermostat Module 5° - 30°C Module	7.95
VM138	DMX Controlled Relay Module	21.74
VM139	IR Remote Checker Module	7.64
VM140	Extender USB Interface Board Module	79.95
VM141	Start/Stop Timer Module	12.95
VM142	Mini-Pic Application Module	26.00
VM143/1W	1W High Power LED Driver Module	9.85
VM143/3W	3W High Power LED Driver Module	9.95
VM144	Telephone Ring Detector & Relay output	14.65
VM145	Digital Panel Thermometer Min/Max	23.35
VM146	RGB Controller Module	22.52
VM147	Panel Counter Module	23.35
VM148	Panel Thermostat Module	26.80
VM150	RGB LED Dimmer for DIN rail *(Due July)*	31.00
VM151	RGB Controller Module & remote control	26.35
VM152	LED Dimmer with RF Remote Control	29.53
VM154	Fan Timer Module	17.55
VM156	Pocket Audio Generator Module	20.00
VM160	4 Channel RF Remote Control Set	47.50
VM160DT	4 Channel RF Desktop Transmitter	46.28
VM160T	4 Channel RF Replacement transmitter	17.05
VM161	RGB LED Strip Colour controller Module	22.75
VM162	RGB LED Strip Colour dimmer Module	30.86
VM163	Panel Clock Module	25.17
VM164	Mini Dimmer, Push button control *(Due July)*	14.78
VM165	0-10V DC Controlled Dimmer *(Due June)*	48.95
VM179	Proximity Card Reader Module	25.65
VM8090	8 Channel USB Relay Card *(Due July)*	58.40

Over 300 Kits, Mini Kits & Modules - check web site for details

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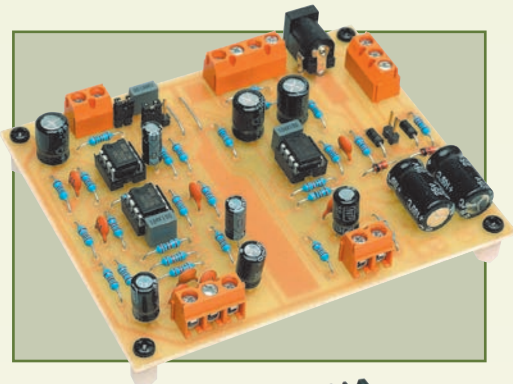

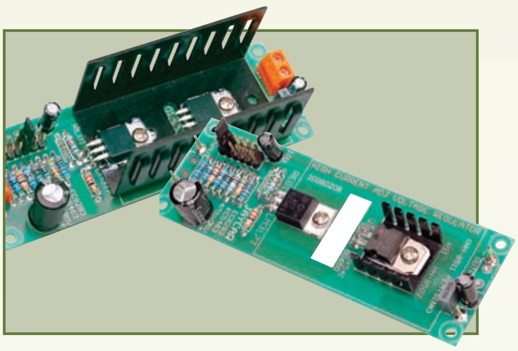

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Series and Features

Regulars and Services

Our October 2010 issue will be published on Thursday 9 September 2010, see page 72 for details.

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PIC & ATMEL Programmers

We have a wide range of low cost PIC and ATMEL Programmers. Complete range and documentation available from our web site.

Programmer Accessories:
40-pin Wide ZIF socket (ZIF40W) £14.95
18Vdc Power supply (PSU120) £19.95
Leads: Parallel (LDC136) £3.95 / Serial (LDC441) £3.95 / USB (LDC644) £2.95

NEW! USB & Serial Port PIC Programmer

USB/Serial connection. Header cable for ICSP. Free Windows XP software. See website for PICs supported. ZIF Socket and USB lead extra. 18Vdc.
Kit Order Code: 3149EKT - **£49.95**
Assembled Order Code: AS3149E - **£59.95**
Assembled with ZIF socket Order Code: AS3149EZIF - **£74.95**

NEW! USB 'All-Flash' PIC Programmer

USB PIC programmer for all 'Flash' devices. No external power supply making it truly portable. Supplied with box and Windows XP Software. ZIF Socket and USB lead not incl.
Assembled Order Code: AS3128 - **£49.95**
Assembled with ZIF socket Order Code: AS3128ZIF - **£64.95**

ATMEL 89xxxx Programmer

Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. Supply: 16Vdc.
Kit Order Code: 3123KT - **£28.95**
Assembled Order Code: AS3123 - **£39.95**

Introduction to PIC Programming

Go from complete beginner to burning a PIC and writing code in no time! Includes 49 page step-by-step PDF Tutorial Manual, Programming Hardware (with LED test section), Win 3.11—XP Programming Software (Program, Read, Verify & Erase), and 1rewritable PIC16F84A that you can use with different code (4 detailed examples provided for you to learn from). PC parallel port.
Kit Order Code: 3081KT - **£16.95**
Assembled Order Code: AS3081 - **£24.95**

PIC Programmer Board

Low cost PIC programmer board supporting a wide range of Microchip® PIC™ microcontrollers. Requires PC serial port. Windows interface supplied.
Kit Order Code: K8076KT - **£39.95**

PIC Programmer & Experimenter Board

The PIC Programmer & Experimenter Board with test buttons and LED indicators to carry out educational experiments, such as the supplied programming examples. Includes a 16F627 Flash Microcontroller that can be reprogrammed up to 1000 times for experimenting at will. Software to compile and program your source code is included.
Kit Order Code: K8048KT - **£39.95**
Assembled Order Code: VM111 - **£59.95**

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code PSU445 £7.95

USB Experiment Interface Board

5 digital input channels and 8 digital output channels plus two analogue inputs and two analogue outputs with 8 bit resolution.
Kit Order Code: K8055KT - **£38.95**
Assembled Order Code: VM110 - **£64.95**

Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 4 indicator LED 's. Rx: PCB 77x85mm, 12Vdc/6mA (standby). Two *& Ten Channel versions also available.*
Kit Order Code: 3180KT - **£49.95**
Assembled Order Code: AS3180 - **£59.95**

Computer Temperature Data Logger

Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor.
Kit Order Code: 3145KT - **£19.95**
Assembled Order Code: AS3145 - **£26.95**
Additional DS1820 Sensors - **£3.95 each**

Remote Control Via GSM Mobile Phone

Place next to a mobile phone (not included). Allows toggle or auto-timer control of 3A mains rated output relay from any location with GSM coverage.
Kit Order Code: MK160KT - **£13.95**

Most items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix).

4-Ch DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12Vdc.
Kit Order Code: 3140KT - **£74.95**
Assembled Order Code: AS3140 - **£89.95**

8-Ch Serial Port Isolated I/O Relay Module

Computer controlled 8 channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130x100x30mm. Power: 12Vdc/500mA.
Kit Order Code: 3108KT - **£69.95**
Assembled Order Code: AS3108 - **£84.95**

Infrared RC 12–Channel Relay Board

Control 12 onboard relays with included infrared remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm. Supply: 12Vdc/0.5A
Kit Order Code: 3142KT - **£59.95**
Assembled Order Code: AS3142 - **£69.95**

Audio DTMF Decoder and Display

Detect DTMF tones from tape recorders, receivers, two-way radios, etc using the built-in mic *or* direct from the phone line. Characters are displayed on a 16 character display as they are received and up to 32 numbers can be displayed by scrolling the display. All data written to the LCD is also sent to a serial output for connection to a computer. Supply: 9-12V DC (Order Code PSU445). Main PCB: 55x95mm.
Kit Order Code: 3153KT - **£34.95**
Assembled Order Code: AS3153 - **£44.95**

Telephone Call Logger

Stores over 2,500 x 11 digit DTMF numbers with time and date. Records all buttons pressed during a call. No need for any connection to computer during operation but logged data can be downloaded into a PC via a serial port and saved to disk. Includes a plastic case 130x100x30mm. Supply: 9-12V DC (Order Code PSU445).
Kit Order Code: 3164KT - **£44.95**
Assembled Order Code: AS3164 - **£59.95**

EVERYDAY PRACTICAL ELECTRONICS

FEATURED KITS

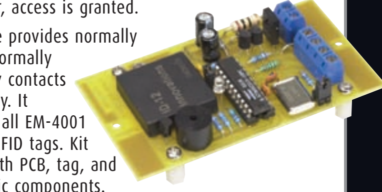
Everyday Practical Electronics Magazine has been publishing a series of popular kits by the acclaimed Silicon Chip Magazine Australia. These projects are 'bullet proof' and already tested down under.
All Jaycar kits are supplied with specified board components, quality fibreglass tinned PCBs and have clear English instructions. Watch this space for future featured kits.

September 2010

RFID SECURITY MODULE RECEIVER KIT

KC-5393 £28.95 plus postage & packing
Radio Frequency Identity (RFID) is a contact-less method of controlling an event such as a door strike or alarm etc. An "RFID Tag" transmits a unique code when energised by the receiver's magnetic field. As long as a pre-programmed tag is recognised by the receiver, access is granted.

This module provides normally open and normally closed relay contacts for flexibility. It works with all EM-4001 compliant RFID tags. Kit supplied with PCB, tag, and all electronic components.



Featured in EPE August 2007

VOLTAGE MONITOR KIT

KC-5424 £6.75 plus postage & packing
This versatile kit will allow you to monitor the battery voltage, the airflow meter or oxygen sensor in your car. The kit features 10 LEDs that illuminate in response to the measured voltage, preset 9-16V, 0-5V or 0-1V ranges, complete with a fast response time, high input impedance and auto dimming for night time driving. Kit includes PCB with overlay, LED bar graph and all electronic components.

- 12VDC
- Recommended box: UB5 use HB-6015 £0.83

Featured in EPE November 2007

IMPROVED LOW VOLTAGE ADAPTOR KIT

KC-5463 £5.25 plus postage & packing
A handy regulator to run a variety of devices such as CD or MP3 players from your car cigarette lighter sockets or even powered speakers from the power supply inside your PC. It will supply either 3V, 5V, 6V, 9V, 12V or 15V and (when used with an appropriate input voltage and heatsink) deliver up to four amps at the selected output voltage. Kit includes screen printed PCB and all specified components. Heatsink not included.

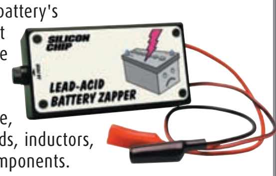
- PCB: 108 x 37mm

Featured in this issue of EPE

FEATURED THIS MONTH

LEAD-ACID BATTERY ZAPPER KIT

KC-5414 £11.75 plus postage & packing
Lead acid batteries are very common in modern life, and are a very versatile power source. Unfortunately, the chemical reaction inside the cells can be the very thing leading it to a premature death. This simple circuit is designed to produce bursts of high-energy pulses to help reverse the damaging effects of sulphation in wet lead acid cells. This is particularly useful when a battery has been sitting for a period of time without use. The effects are dependant of the battery's condition and type, but the results can be quite good indeed.

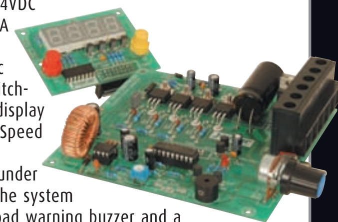


- Kit supplied with case, silk screened lid, leads, inductors, and all electronic components.

Featured in EPE July 2007

HIGH CURRENT MOTOR SPEED CONTROLLER KIT

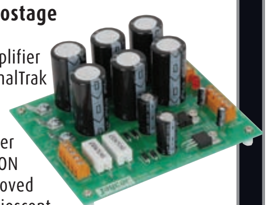
KC-5465 £26.25 plus postage & packing
Controls a 12 or 24VDC motor at up to 40A continuous and features automatic soft-start, fast switch-off and a 4-digit display to show settings. Speed regulation is maintained even under heavy loads and the system includes an overload warning buzzer and a low battery alarm. Kit contains PCB and all specified electronic components.



Featured in EPE December 09/January 10

ULTRA-LOW DISTORTION 135WRMS AMPLIFIER MODULE

KC-5470 £27.75 plus postage & packing
This ultra low distortion amplifier module uses the new ThermalTrak power transistors and is largely based on the high-performance Class-A amplifier which was featured in SILICON CHIP during 2007. This improved circuit has no need for a quiescent current adjustment or a Vbe multiplier transistor and has an exceptionally low distortion figure. Kit supplied with PCB and all electronic components. Heat sink and power supply not included.



FEATURED THIS MONTH

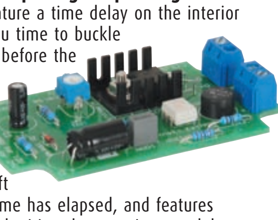
Output Power: 135WRMS into 8 ohms and 200WRMS into 4 ohms
Frequency Response at 1W: 4Hz to 50kHz
Harmonic Distortion: <0.008% from 20Hz to 20kHz

Also available:
Power Supply Kit for Ultra-LD Mk2 200W Amplifier (KC-5470) - KC-5471 £16.25

Featured in this issue of EPE

COURTESY INTERIOR LIGHT DELAY KIT

KC-5392 £6.00 plus postage & packing
Many modern cars feature a time delay on the interior light. It still allows you time to buckle up and get organised before the light dims and finally goes out. This kit provides that feature for cars which don't already provide it. It has a soft fade out after a set time has elapsed, and features much simpler universal wiring than previous models we have had.



- Kit supplied with PCB with overlay, and all electronic components.
- Suitable for circuits switching ground or +12V or 24VDC (car & truck with negative chassis.)
- PCB: 78 x 46mm

Featured in EPE February 2007

PROGRAMMABLE HIGH ENERGY IGNITION KIT

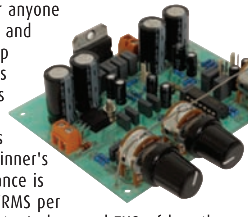
KC-5442 £27.75 plus postage & packing
This advanced and versatile ignition system is suited for both two & four stroke engines. Used to modify the factory ignition timing or as the basis for a stand-alone ignition system with variable ignition timing, electronic coil control and anti-knock sensing.

- Timing retard & advance over a wide range
- Suitable for single coil systems
- Dwell adjustment
- Single or dual mapping ranges
- Max & min RPM adjustment

Featured in EPE September/October/November 2009

HIGH PERFORMANCE 12V STEREO AMPLIFIER KIT

KC-5495 £13.25 plus postage & packing
An ideal project for anyone wanting a compact and portable stereo amp where 12V power is available. No mains voltages, so it's safe as a schoolie's project or as a beginner's first amp. Performance is excellent with 20WRMS per channel at 14.4V into 4 ohms and THD of less than 0.03%. Shortform kit only. Recommended heatsink Cat. HH-8570 £2.00



- PCB: 95 x 78mm
- 12VDC

new

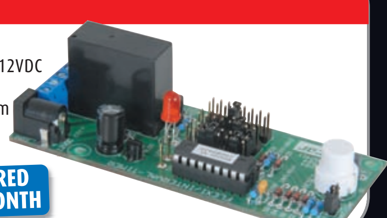
LOW COST PROGRAMMABLE INTERVAL TIMER KIT

KC-5464 £10.25 plus postage & packing
Here's a new and completely updated version of the very popular low cost 12VDC electronic timer. It is link programmed for either a single ON, or continuous ON/OFF cycling for up to 48 on/off time periods. Selectable periods are from 1 to 80 seconds, minutes, or hours and it can be restarted at any time. Kit includes PCB and all specified electronic components.

- PCB: 102 x 42mm

Featured in this issue of EPE

FEATURED THIS MONTH



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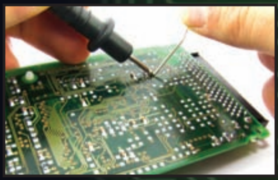
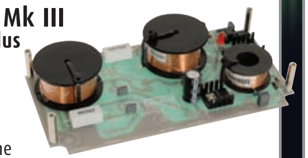


POWER / SOLAR KITS FOR ELECTRONIC ENTHUSIASTS

BATTERY KITS

Battery Zapper Mk III
KC-5479 £23.25 plus postage & packing



The popular battery zapper kit has gone through a couple of upgrades and this is the latest easier-to-build version. Like the original project from 2005, it attacks a common cause of failure in lead acid batteries: sulphation, which can send a battery to an early grave. The circuit produces short bursts of high levels of energy to reverse the sulphation effect. The battery condition checker is no longer included and the circuit has been updated and revamped to provide more reliable, long-term operation. It still includes test points for a DMM and binding posts for a battery charger.

- Not recommended for use with gel batteries
- PCB with solder mask and overlay
- Components
- Screen printed machined case
- 6, 12 & 24VDC

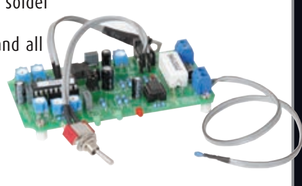
SLA Battery Health Checker Kit
KC-5482 £23.25 plus postage & packing

The first versions of the battery zapper included a checker circuit. The Mk III battery zapper (KC-5479) has a separate checker circuit - and this is it. It checks the health of SLA batteries prior to charging or zapping with a simple LED condition indication of fair, poor, good etc.

- Overlay PCB and electronic components
- Case with machined and silk-screened front panel
- PCB: 185 x 101mm

Fast Ni-MH Battery Charger Kit
KC-5453 £12.50 plus postage & packing

Capable of handling up to 15 of the same type of Ni-MH or Ni-Cd cells. Build it to suit any size cells or cell capacity and set your own fast or trickle charge rate. It also has overcharge protection including temperature sensing. Kit includes solder mask & overlay PCB, programmed micro and all specified electronic components. Case, heatsink and battery holder not included.

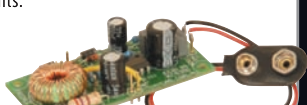


- PCB: 98 x 53mm

3V to 9V DC to DC Converter Kit
KC-5391 £4.75 plus postage & packing

This great little converter allows you to use regular Ni-Cd or Ni-MH 1.2V cells, or Alkaline 1.5V cells for 9V applications. Using low cost, high capacity rechargeable cells, the kit will pay for itself in no-time! You can use any 1.2-1.5V cells you desire. Kit supplied with PCB, and all electronic components.

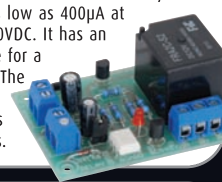
- PCB: 59 x 29mm



DC RELAY SWITCH KIT

KC-5434 £5.00 plus postage & packing

An extremely useful and versatile kit that enables you to use a tiny trigger current - as low as 400µA at 12V to switch up to 30A at 50VDC. It has an isolated input, and is suitable for a variety of triggering options. The kit includes PCB with overlay and all electronic components with clear English instructions.



UNIVERSAL VOLTAGE SWITCH

KC-5377 £9.75 plus postage & packing

This is a universal module which can be adapted to suit a range of different applications. It will trip a relay when a preset voltage is reached. It can be configured to trip with a rising or falling voltage, so it is suitable for a wide variety of voltage outputting devices eg., throttle position sensor, air flow sensor, EGO sensor. It also features adjustable hysteresis (the difference between trigger on/off voltage), making it extremely versatile. You could use it to trigger an extra fuel pump under high boost, anti-lag wastegate shutoff, and much more. Kit supplied with PCB, and all electronic components.

- PCB Dimensions: 105 x 60mm

VOLTAGE MODIFIER KIT

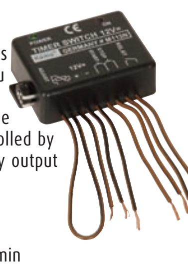
KC-5490 £23.25 plus postage & packing

This kit intercepts and alters the signal from engine sensors that supply a voltage signal to the engine control unit (ECU). Restore correct air/fuel ratios after engine modifications, prevent engine boost cuts or alter sensor signals for improved driveability. Requires hand controller for programming, RS-232 cable and a suitable input signal. Kit includes PCB, case and electronic components.

- 12VDC
- PCB, case and components

12V 3A TIMER MODULE

AA-0364 £10.25 plus postage & packing



A versatile and useful timer module that can be set for periods of 2 seconds to 10 minutes. If you add a 500k pot you can extend the time period to 30 minutes. The start and stop functions are controlled by simple switch inputs and the relay output can control a device of up to 3A.

- Operating voltage: 12V
- Current consumption: 20mA
- Time adjustment: 30 sec to 10 min
- Dimensions: 60(L) x 45(W) x 20(H)mm

POWER KITS

Emergency 12V Lighting Controller
KC-5456 £20.50 plus postage & packing

Automatically supplies power for 12V emergency lighting during a blackout. The system has its own 7.5Ah SLA battery which is maintained via an external smart charger. Includes manual override and over-discharge protection for the battery. Kit supplied with all electronic components, screen printed PCB, front panel and case. Charger and SLA battery available separately.

Motor and Lamp Controller
AA-0347 £15.50 plus postage & packing

Continuously controls the speed of 12VAC motors and can also be used as a dimmer for incandescent lamps. With the addition of a rectifier, it can also be used to control DC motors and if you add a 100k or 200k pot, you can control 24 or 48V devices. Suitable for iron core transformers only.

- Mode of operation: Phase control
- Control range: approx. 0 - 90 %
- Loading capacity: for resistive or inductive loads up to 10A max
- Dimensions: approx. 87(L) x 60(W) x 32(H)mm

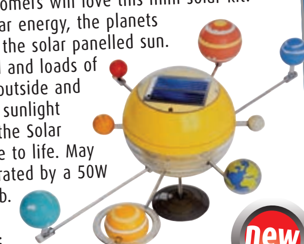
NEW SOLAR KITS!

3-In-1 Solar Robot Kit
KJ-8928 £7.25 plus postage & packing

A 3-in-1 solar robot kit that easily transforms into three intergalactic robotic designs. See how solar power drives the motor forcing three robots to make different movements. On a cloudy day, have some indoor fun and use a 50W halogen light. Projects include a tank, robot and a scorpion.

Solar Powered Planetarium
KJ-8927 £7.25 plus postage & packing

Young astronomers will love this mini solar kit. With real solar energy, the planets orbit around the solar panelled sun. Easy to build and loads of fun, take it outside and under direct sunlight then watch the Solar system come to life. May also be operated by a 50W halogen bulb.



new

Kit Includes:
- 6 colours of opaque acrylic paints and paint brush
- Planets including Earth, Mars and Jupiter
- Solar panel with motor
- Detailed instruction manual

Suitable for ages 10+

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Editorial Offices:
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Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU
Phone: (01202) 873872. Fax: (01202) 874562.
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VOL. 39 No. 9 SEPTEMBER 2010

Don't be scared of maths!

Circuit Surgery is consistently one of the most popular and commented on sections in EPE. It is well written, relevant, practical and directly responds to reader enquiries. Like the other regular EPE authors, Ian Bell manages to provide useful advice without resorting to complicated mathematics or obscure physical phenomena. However, this month's article is a little different. In it, Ian tackles an important concept in amplifier design – total harmonic distortion, or THD for short. THD is one of the most oft-quoted figures when describing the quality of an amplifier, and is a firm favourite of commercial hifi manufacturers when they want to show off their new shiny boxes – but how do we explain its meaning?

Well, it turns out that describing THD without a little mathematics would involve leaving out some pretty important ideas. Therefore, Ian has taken the decision to include equations that at first sight are perhaps more challenging than you might expect to see in this magazine. Please do not be put off! – or worry that EPE is about to become an academic journal, it isn't. For those of you who see yourselves as not particularly comfortable with maths, do give Ian the benefit of the doubt and give the article a good read. The maths is actually not as daunting as it first looks, and if you get real intellectual satisfaction from solving a tricky circuit design problem, then you are also likely to get the same 'buzz' from mastering an equation or two.

EPE is definitely not going to turn into a equation-heavy design publication. However, it is occasionally worth seeing how some of the more mathematical aspects of our fascinating hobby work. Plus, I hope that for some of you, it will stimulate enough interest to pursue this side of electronics a little further, because a little maths goes a long way in electronics!

Matt

Editor: MATT PULZER
Consulting Editor: DAVID BARRINGTON
Subscriptions: MARILYN GOLDBERG
General Manager: FAY KEARN
Editorial/Admin: (01202) 873872
Advertising and Business Manager: STEWART KEARN (01202) 873872
On-line Editor: ALAN WINSTANLEY
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Publisher: MIKE KENWARD

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A number of projects and circuits published in *EPE* employ voltages that can be lethal. You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.

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We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers.
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NEWS

A roundup of the latest Everyday News from the world of electronics

Switch off moves to the slow lane By Barry Fox

THE new UK government has now distanced itself from the unrealistic 2015 date for switching off analogue radio – and made it clear that the date came from the broadcast industry. I have questioned Ed Vaizey, minister for culture, communications and creative industries, on this topic three times recently, and it was quickly clear that he is a rare species – a politician who likes to find out facts for himself, rather than rely on what advisers tell him.

On the first occasion, Vaizey was at Digital UK's update on the digital TV switchover.

'In an attempt to make myself the most unpopular minister in government, I intend to press ahead with digital radio switchover' he said. 'We need to address the myths that surround switchover'.

I asked Vaizey when he would set out a realistic plan for digital radio switchover, which consumers would not mock and thus ignore, as they have been mocking and ignoring the 2015 fantasy.

'Thursday', said Ed Vaizey, unequivocally. 'I will set out a plan this Thursday. But I can't stop the public mocking it.'

Thursday came, and Vaizey spoke at the *Intellect* conference in London. '2015 is the target that the industry thinks is achievable' he said. 'That date is not set in stone. It will have to be driven by listeners.'

'We agree that 2015 is appropriate if, and it's a big if, consumers are supporting it. We will only consider that date when more than 50% of listening is digital – in other words analogue is in the minority'.

'I realised quickly that this could turn into a major row. So I can say clearly that we will not switch off until the vast majority of listeners have voluntarily switched over.'

'2015 remains a target date to aspire to that the industry came up with. There is a lot more work to be done before we can support it. Listeners are passionate about radio. We got a glimpse of that with the furore that followed the BBC's announcement – now reversed – that it would close the *Radio 6* digital music station.'

Acknowledging the challenge of persuading car manufacturers to factory-fit digital radios, and convert the many millions of existing cars with only analogue FM radios and aerials, Vaizey pledged to meet all the car manufacturers 'soon'.

I suggested Vaizey try for himself using a Pure Highway DAB converter and hunt in vain for free FM frequencies in urban areas to use for FM re-broadcast to an analogue dash radio.

A Digital Radio UK (DRUK) spokeswoman had previously brushed aside my concern that the few gaps between broadcast stations are swamped by pirate stations. She had no trouble finding frequencies where she lived, she assured; but it turned out she drove in rural Scotland.

My third encounter with Ed Vaizey was at a social event at the House of Commons. He told me he was paying Halfords £100 to have a Highway fitted to his car.

So now someone at policy level will finally understand why 'analogue vehicles' are the main reason analogue radio cannot end in 2015. There will still be a legacy of around 20 million on the road.

At the *Intellect* event DRUK was distributing leaflets, which state baldly that 'the motor industry has committed to ensuring that all cars are digitally enabled from 2013'. This is what DRUK had told me in late June, along with talk of a scheme to convert cars to DAB for under £100 during routine service or MOT.

But when I checked with the Society of Motor Manufacturers and Traders (SMMT), which is a member of DRUK, the SMMT flatly renounced the sub-£100 price and carefully qualified that new car DAB fitting 'may not necessarily be as standard.'

The SMMT has now confirmed that it was 'not aware of the leaflet... and will contact DRUK to discuss the details.'

If the trade body tasked with turning the UK onto digital radio cannot agree on key facts, it will have a hard time winning support from Ed Vaizey.

University reaches 20 million downloads on iTunes U

THE Open University (OU) has reached a milestone as the first university to hit 20 million downloaded tracks on iTunes U, a dedicated area within the iTunes Store (**www.itunes.com**). With an average of over a quarter of a million downloads per week, the OU's popularity has soared since its content was first made available on iTunes U in June 2008.

Most people downloading OU's tracks do so to continue their own education, with 96% of respondents to an OU audience survey saying that they use the materials for learning. An upsurge in people accessing OU student websites on their mobile devices reinforces the increasing popularity of more flexible content like the materials on iTunes U.

In June 2008, when The Open University on iTunes U was launched, 1,370 students accessed the OU's student websites via their mobile devices – in May 2010, this had risen massively to over 11,000 unique student visitors in that month alone.

Over 4.5 million downloads from The Open University on iTunes U in the past year relate to tracks in science, technology, engineering and maths (STEM) subjects – accounting for 28% of the total downloads in that time.

Anyone can download OU tracks from iTunes U for free, and the most popular collections from The Open University on iTunes U have been languages and arts with the most downloaded to date being Beginner's French.

‘Star Wars’ becomes a reality

IT SOUNDS like technology from a science fiction film, a Raytheon-U.S. Navy team has demonstrated a high power, solid-state laser combined with a Phalanx close-in weapon system to shoot down four unmanned aerial vehicles (UAV) off San Nicolas Island near California.

Powered by electricity, the system offers an affordable and near-infinite amount of ‘ammunition’ to stop incoming threats. Once development is completed, the Laser Area Weapon System will give the warfighter a speed-of-light solution for defeating rockets, mortars, UAVs and other targets.

Raytheon aims to be a major player in the US Army’s Common Infrared Countermeasures competition. Raytheon Missile Systems has developed a system known as *Scorpion* that will feature the company’s directed infrared countermeasures turret and a rugged quantum cascade laser (QCL). Scorpion is intended to be a be a light-weight, low-cost, highly reliable, laser-based infrared countermeasures solution against current and the threat of future IR guided missiles.

‘Directed energy essentially gives warfighters an unlimited magazine. As long as they have electricity they have photons, and as long as they have photons they have bullets’, said Mike Booen, Raytheon’s vice president of Advanced Security and Directed Energy Systems.

Neurostimulator implant

A GROUND-BREAKING pain management device featuring technology similar to that found in the iPhone and Wii remotes has been implanted into a patient for the first time in the UK by doctors at Guy’s and St Thomas’ hospital.

The neurostimulator will treat chronic back pain using ‘spinal cord stimulation’ (SCS). This is where mild electrical pulses are delivered to the spinal cord to mask the body’s pain signals and replace them with a tingling sensation.

The neurostimulator is the first in the world to use motion-sensing technology similar to the spirit level function in iPhone or Wii remotes. It senses a change in the patient’s body position or activity level and automatically adjusts how much pain relieving stimulation to deliver. For example, if the patient is lying on their back then a lower stimulation will be delivered, but if they are lying on their front then a higher-dose will be delivered.

Until now, patients have only been able to use devices that deliver pre-set levels of constant stimulation, which meant they had to frequently change their pain-relief settings manually whenever they changed position or activity. This often led to spinal cord stimulation users experiencing broken sleep due to inadequate pain relieving stimulation.

The device, called a RestoreSensor, was designed in the US and features technology that uses the force and direction of the Earth’s gravity to sense the patient’s position. It also houses its own ‘black box’ which records and stores the frequency of the posture and activity changes. This data, available for the first time in an SCS device, helps the clinician know whether the patient’s activity level and individual stimulation requirements are changing over time.

Dr Adnan Al-Kaisy, one of the world’s leading pain management consultants, carried out the first procedure using the RestoreSensor. He said: ‘This is a very significant improvement on traditional spinal cord stimulation implants because for the first time it will automatically increase or reduce the pain relief the patient receives – particularly during the night. I’ve been working in this field for 15 years and this is the technology we have always dreamt of.

‘We expect it to be used with some patients who suffer from severe leg or back pain, or post-surgery problems, who have not responded to traditional therapy or medication. When successful, it reduces pain by around 80%, and patient satisfaction and quality of life will be very high.’

Black silicon

SiONYX Inc, in collaboration with the United States Army Research Office, has demonstrated pixel-scale detectors with room temperature ‘detectivity’ ten-times better than traditional silicon detectors.

SiOnyx is developing a new semiconductor processing technique to produce smaller, cheaper, high-performing silicon photonic devices. Based on a novel laser implant method first discovered at Harvard and commonly referred to as ‘Black Silicon,’ SiOnyx’s semiconductor process dramatically enhances the performance of light-sensing devices in the consumer, industrial, medical and defence industries.

World’s smallest transistor

SCIENTISTS from the University of New South Wales Centre and the University of Wisconsin-Madison have taken a leap into a new era of computing power by making the world’s smallest precision-built transistor of just seven atoms in a single silicon crystal.

Despite its incredibly tiny size – a mere four billionths of a metre long – the ‘quantum dot’ is a functioning electronic device, the world’s first created deliberately by placing individual atoms.

It can be used to regulate and control electrical current flow like a commercial transistor, but it represents a key step into a new age of atomic-scale miniaturisation and super-fast, super-powerful computers.

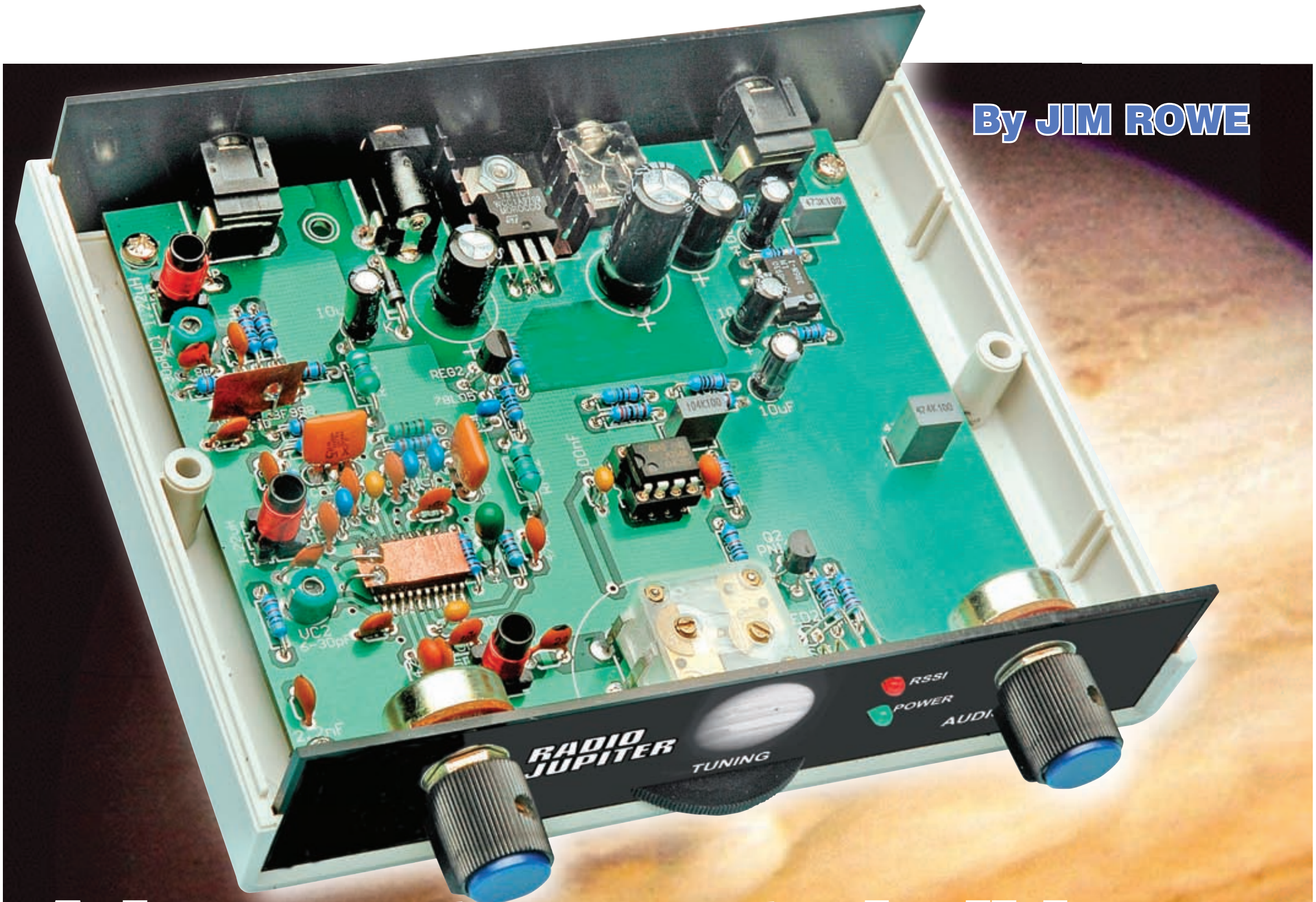
Mouse sensor

PARALLAX has announced the Parallax Mouse Sensor, a module in kit form, which when assembled, provides the tracking functions of an optical mouse. The two-wire serial interface is directly compatible with the Parallax BASIC Stamp family, the Parallax Propeller, and other microcontrollers.

This kit has a distinct advantage for experimenters over off-the-shelf computer mice, in that the mechanical parts are more hacker-friendly, and the programming does not rely on interfacing to (or bypassing) a USB or PS/2 connection. Features include:

- Compact module, including illumination, optics, and custom laser-cut base
- ‘Close-to-the-metal’ register-based serial interface for maximum flexibility
- Holes for mounting to other equipment
- Compatible with any BS2-family BASIC Stamp, the SX, and the Parallax Propeller
- Accommodation for single/dual three-wire (servo-type) interface cables (included)

For more details, visit: **www.parallax.com**.



By JIM ROWE

A low-cost, easy-to-build Planet Jupiter Receiver

How would you like to try some basic radio astronomy – listening to the bursts of noise originating from the planet Jupiter, or from the Sun? You don't need a lot of fancy equipment to do this, just the simple shortwave receiver described here. It's hooked up to a basic dipole antenna (which we describe as well) and to the sound card in your PC, so that you can print out 'chart recordings' of the noise signals.

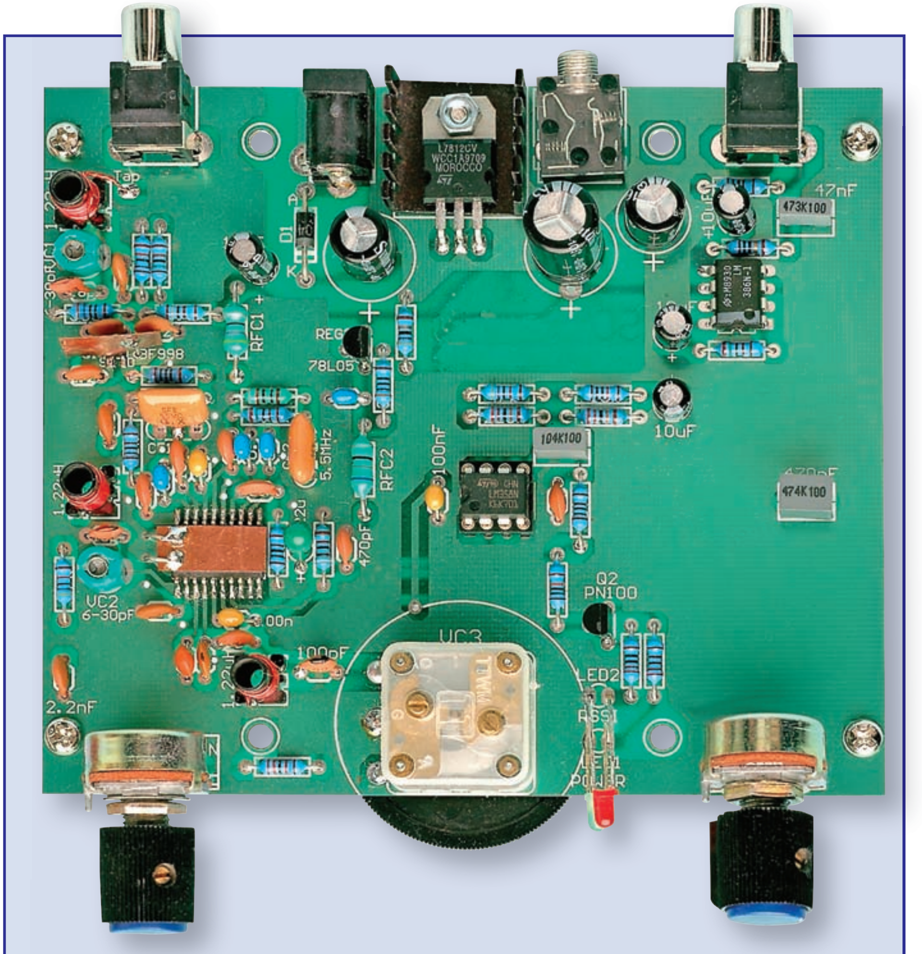
MENTION the term 'radio astronomy' to most people, and they'll either look completely blank or visualise huge steerable dishes – like the one at Jodrell Bank in Cheshire. While a lot of radio astronomy is done nowadays using huge 'valley sized' antennas like the one at Aricebo in Puerto Rico, or big arrays of smaller antennas, it's still possible to do interesting observations using much simpler antennas and equipment, at 'decametric' frequencies (8-30MHz) in the HF radio band.

In fact, a NASA-sponsored project called '*Radio Jove*' has been promoting this type of radio astronomy for the last 10 years as a science project for high-school students and interested hobbyists. Over 1000 simple receiver kits have been sold, for 20.1MHz reception of noise bursts from the planet Jupiter, the Sun and other objects in the Milky Way galaxy.

There's only one problem with the US-designed Radio Jove receiver as far as non-US students and hobbyists have been concerned: the receiver kits cost US$155 each, plus shipping from the States, so it will set you back quite a lot to have one sent to you. This has discouraged more than a handful of people from radio astronomy.

To encourage more students and hobbyists to have a go, we have developed our own low-cost receiver project. And that's the background to the new receiver described in this article. You'll find its basic specifications summarised in the 'Main Features' panel, but the bottom line is that it's quite suitable for basic radio astronomy at decametric frequencies around 21MHz. This makes it fine for receiving noise bursts from Jupiter, the Sun or other sources in the Milky Way.

We estimate that it will cost you around £50 for the basic receiver module, plus a 'fiver' if you decide to house it in an ABS instrument box. In other words, less than half the cost of the Radio Jove receiver. We also think it is a much better design, by the way.



The parts for the Jupiter Receiver are all mounted on a double-sided PC board. The top groundplane pattern is necessary to ensure stability.

How it works

The complete circuit for the receiver is shown in Fig.1. The heart of the circuit is IC1, an SA605D single-chip receiver IC that includes a local oscillator, an RF mixer, a high-gain IF amplifier and an IF limiting amplifier, plus a quadrature detector for FM signal demodulation.

We are not using the last of these sections here, because we're using the SA605 in a slightly unusual way – for AM signal demodulation. We do this by taking advantage of the chip's RSSI (received signal strength indicator) output from pin 7.

This works because associated with the high-gain IF amplifier and limiter stages inside the SA605 are a number of signal level detectors, whose outputs are combined to provide a DC output current from pin 7. This DC output current is logarithmically proportional to the incoming signal strength, so it is essentially an AM detector output. We convert it into a voltage signal by passing the current through a 91kΩ load resistor, shunted by a 470pF capacitor for low-pass filtering.

The centre intermediate frequency (IF) of the receiver is set at 5.5MHz using ceramic filters CF1 and CF2. These require no alignment. The local oscillator circuit inside IC1 is brought out to pins 3 and 4, to which we connect frequency-determining components L3 and VC3, together with 22pF and 39pF capacitors. Together, these components allow the local oscillator to be tuned manually over the range 25.75MHz to 28.0MHz, which is 5.5MHz above the input signal range of interest (20.25-22.5MHz).

The use of a 5.5MHz IF means that the receiver's image frequency will be 11MHz above the wanted frequency – giving a good image rejection ratio.

The input of IC1's mixer stage is tuned to the centre of the wanted frequency band (ie, about 21MHz) by

Main Features

The receiver is a single-conversion superhet design, tuning from about 20.25MHz to 22.5MHz, with a sensitivity of approximately 1μV for a 10dB signal-to-noise ratio. Only three controls are provided: RF gain, tuning and audio gain.

All components are mounted directly on a small PC board measuring only 117mm × 102mm, which can either be used 'naked' or housed in a standard low-profile ABS instrument case (140mm × 110mm × 35mm).

The receiver can be powered from either a 12V battery or a mains plugpack supply delivering between 15V to 18V DC. The current drain is typically between 55mA and 75mA.

There are two audio outputs from the receiver: 1) a line output suitable for connection to the line-level input of a PC sound card, and 2) a low-impedance output capable of driving external headphones or a small 8Ω speaker. Both outputs can be used at the same time.

Parts List – Planet Jupiter Receiver

1 double-sided PC board, code 771, available from the *EPE PCB Service*, size 117mm × 102mm
1 plastic case, 140mm × 110mm × 35mm (optional)
2 Murata 5.5MHz ceramic filters (CF1, CF2)
3 mini RF coil formers (Jaycar LF-1227 or similar) (L1 to L3)
1 300m length of 0.25mm enamelled copper wire
1 47μH RF choke (RFC1)
1 68μH RF choke (RFC2)
2 trimmer capacitors, 6.3pF to 30pF (green) (VC1, VC2)
1 10pF to 120pF miniature 'transistor radio' tuning capacitor, with edgewise knob (VC3) (Jaycar RV-5728)
1 50kΩ 16mm rotary PC-mount *linear* pot (VR1)
1 50kΩ 16mm rotary PC-mount *log* pot (VR2)
2 16mm-diameter control knobs
1 8-pin DIL socket (for IC2)
2 PC-mount RCA phono sockets (CON1, CON2)
1 3.5mm PC-mount stereo jack (CON3)
1 2.5mm PC-mount concentric DC power socket (CON4)
1 TO-220/6093B finned heatsink
4 M3 × 10mm tapped spacers
5 M3 × 6mm machine screws
5 M3 nuts (two used as spacers for VC1)
2 M2.5 × 5mm machine screws (for VC1)
1 15 × 7mm copper sheet or tinplate (for IC1 shield)
1 14 × 10mm copper sheet or tinplate (for Q1 shield)
1 3.5mm mono jack plug to 3.5mm mono jack plug audio cable

Semiconductors
1 SA605D surface-mount single-chip receiver IC (IC1)
1 LM358 dual op amp (IC2)
1 LM386 audio amplifier (IC3)
1 7812 +12V voltage reg.(REG1)
1 78L05 +5V voltage reg. (REG2)
1 BF998 dual-gate MOSFET (Q1)
1 PN100 *NPN* transistor (Q2)
1 3mm green LED (LED1)
1 3mm red LED (LED2)
1 1N4004 diode (D1)
1 16V 1W Zener diode (optional)

Capacitors
1 2200μF 16V radial electrolytic
1 470μF 25V radial electrolytic
1 330μF 16V radial electrolytic
1 22μF 16V tag tantalum
4 10μF 16V radial electrolytic
1 470nF MKT metallised polyester
8 100nF monolithic ceramic
1 47nF MKT metallised polyester
6 10nF monolithic ceramic
7 2.2nF disc ceramic
1 470pF disc ceramic
2 39pF NPO disc ceramic
1 22pF NPO disc ceramic
2 18pF NPO disc ceramic

Resistors (0.25W 1%)

2 220kΩ	2 1.5kΩ
1 150kΩ	5 1kΩ
1 110kΩ	1 820Ω
1 100kΩ	1 360Ω
1 91kΩ	1 300Ω
2 47kΩ	1 220Ω
1 22kΩ	1 100Ω
1 10kΩ	1 47Ω
1 2.2kΩ	2 10Ω
1 1.8kΩ	

Antenna Parts
1 UB5 plastic box, 83 × 54 × 31mm
1 35 × 21 × 13mm ferrite toroid (Jaycar LO-1238 or similar)
50-ohm coaxial cable plus RCA phono plug for downlead

means of inductor L2 and trimmer capacitor VC2. The 'Q' of this circuit is fairly low, so that the receiver's sensitivity is reasonably constant over the 2MHz-wide tuning band. As a result, tuning is achieved purely by adjusting the local oscillator frequency.

Although the SA605 IC does provide a great deal of gain in the IF amplifier and limiter sections, we have included an RF amplifier stage ahead of the IC to ensure that the receiver has adequate sensitivity. As you can see, this RF stage uses a BF998 dual-gate MOSFET (Q1), with the second gate (G2) voltage adjusted via VR1 to allow easy control of RF gain.

The RF input signal from the antenna enters the receiver via CON1, and is fed into the input tuned circuit (L1/VC1) via an impedance-matching tap on inductor L1. As before, the 'Q' of this circuit is kept relatively low, so once it's tuned to about 21MHz it does not need to be changed.

From the RSSI output of IC1, the demodulated audio signals are passed through op amp IC2a (half of an LM358) which is connected as a voltage follower for buffering. They then pass through a simple low-pass RC filter (the 1kΩ resistor and 10nF capacitor) before being fed to IC2b. This is the other half of the LM358 and is configured as an audio amplifier with a gain of ×5.7, as set by the 47kΩ and 10kΩ feedback resistors.

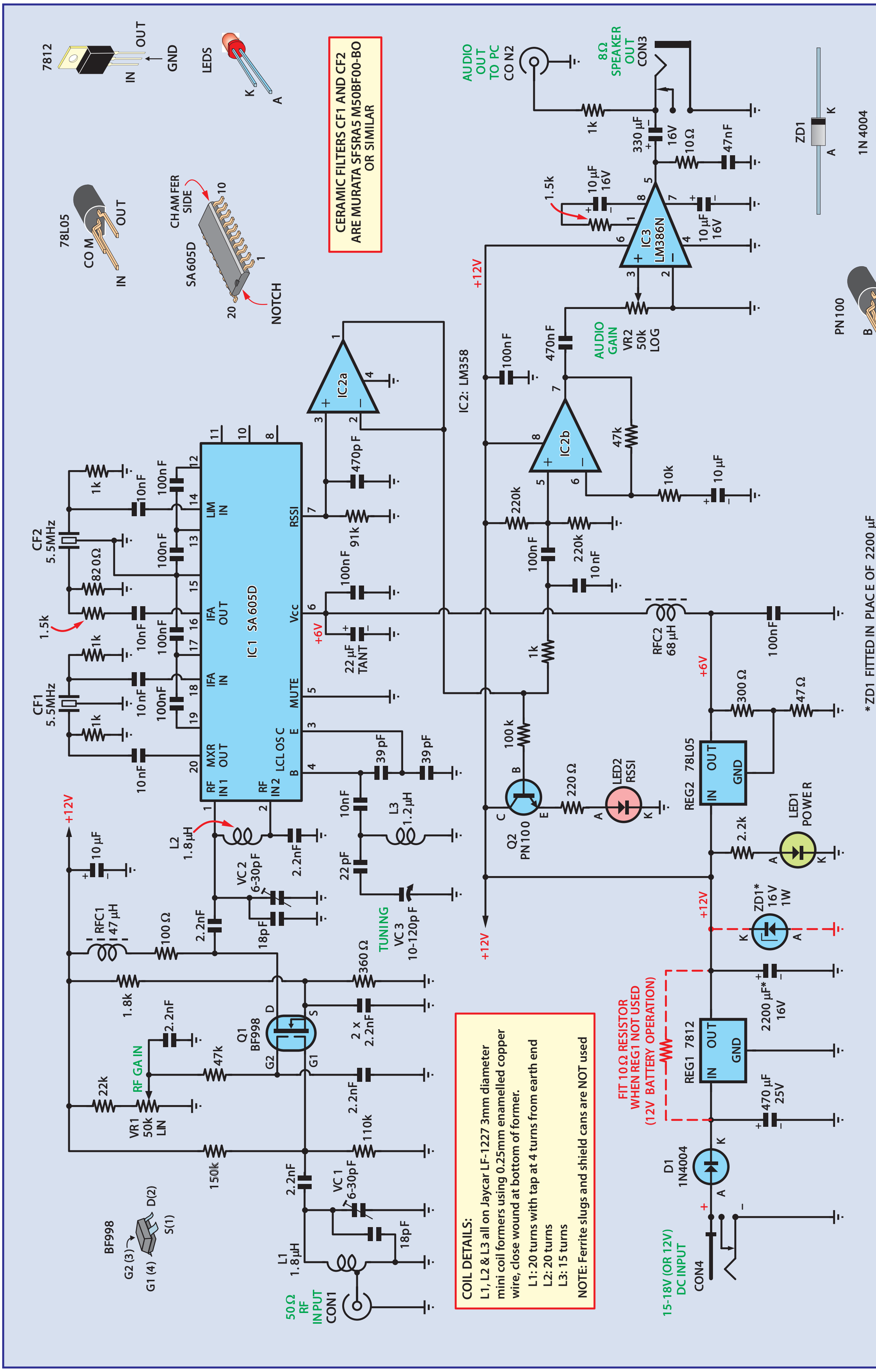
From IC2b, the signals pass through a 470nF coupling capacitor to VR2, the volume/audio gain control. They are then fed through IC3, an LM386N audio amplifier configured here to provide a gain of about ×40. The amplified audio signals are then coupled via a 330μF output capacitor to speaker output jack CON3, and also to line output socket CON2 via a 1kΩ isolating resistor.

Notice that the buffered RSSI signal from the output of IC2a is also fed to transistor Q2, which is used to drive LED2, the RSSI/overload indicator. Because Q2 does not conduct until the output voltage from IC2a reaches a level of around +2.65V, this means that LED1 really only lights when a very strong signal is being received – ie, when the receiver is tuned to a shortwave radio transmission or some other strong terrestrial signal source. So the main purpose of LED2 is to help you tune *away* from such signals, rather than *to* them.

Power supply

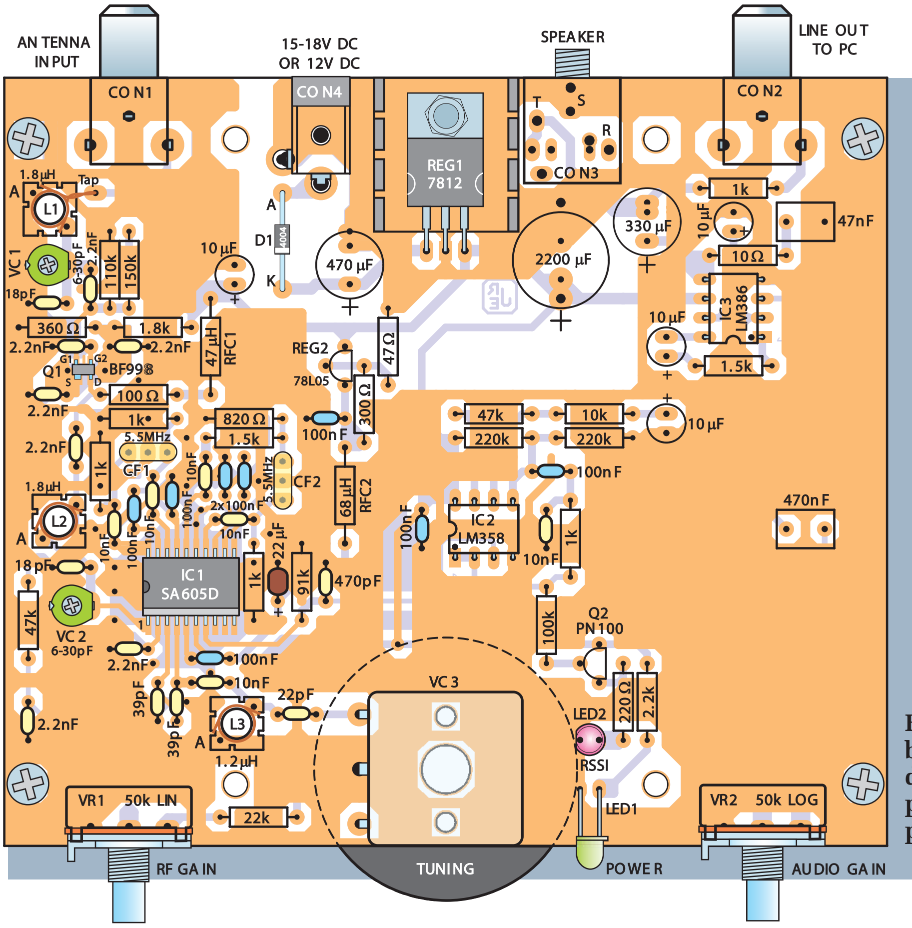
The receiver's power supply is very straightforward. Most of the circuitry operates from +12V, which can come directly from a battery if you wish. In this case regulator REG1 is not used, but is instead replaced by a 10Ω resistor. The 2200μF capacitor is also replaced by a 16V 1W Zener diode, to protect the circuit from damage in case of higher-voltage transients (when the battery is being charged, for example).

On the other hand, if you wish to operate the receiver from a 15V to 18V DC source such as a mains plugpack supply, then this is very easy to do. In this case, REG1 is fitted to regulate the supply down to +12V, while a 2200μF



21MHZ 'PLANET JUPITER' RECEIVER

Fig.1: the circuit is based on an SA605D surface-mount single-chip receiver IC (IC1), which includes a local oscillator, an RF mixer, a high-gain IF amplifier and an IF limiting amplifier, plus a quadrature detector for FM signal demodulation. The latter feature is not used here. Instead, the SA605 is used in a slightly unusual way to obtain AM signal demodulation.



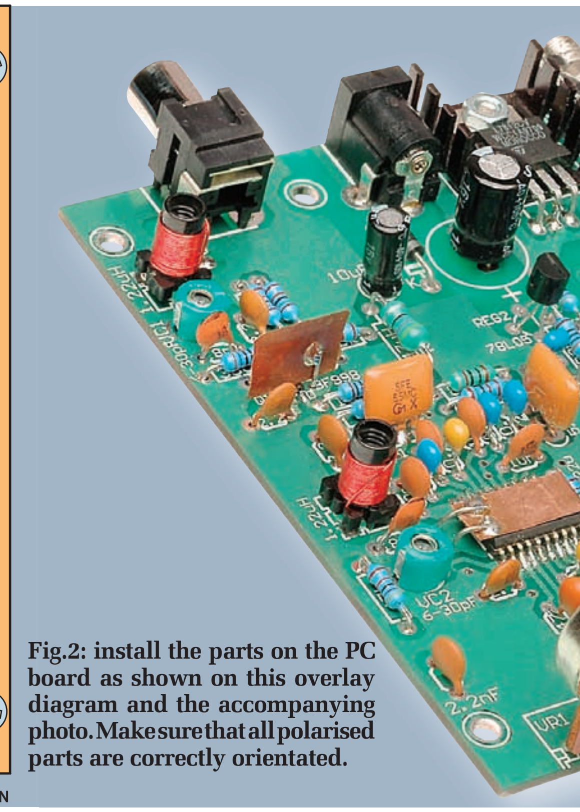


Fig.2: install the parts on the PC board as shown on this overlay diagram and the accompanying photo. Make sure that all polarised parts are correctly orientated.

capacitor is also fitted to provide the necessary filtering.

The only part of the receiver which does not operate directly from the +12V line is IC1, which needs a supply of +6V. This is provided by REG2, a low-power 5V regulator arranged here to provide an output of +6V by means of the 300Ω/47Ω resistive divider across its output.

LED1 is connected to the +12V supply via a 2.2kΩ series resistor to provide power indication, while diode D1 is in series with the DC input to protect against reverse-polarity damage.

Construction

As you can see from the photos, all of the receiver's parts are mounted on a small double-sided PC board measuring 117mm × 102mm and coded 771. This board is available from the *EPE PCB Service*. The printed circuit board component layout is shown in Fig.2.

As the double-sided PCB is not a plated through hole type, constructors will have to take extreme care when soldering components in position on the board – especially around IC1, a surface-mount device, where a sound 'earth plane' is essential for stability. Some components will need soldering on both sides.

The two black dots by the left side of IC1 are where its 'shield' leads are soldered to both sides of the board – see text. You will also need a vertical shield for MOSFET Q1. Other spare holes on the board need to be 'pinned' through to the underside tracks.

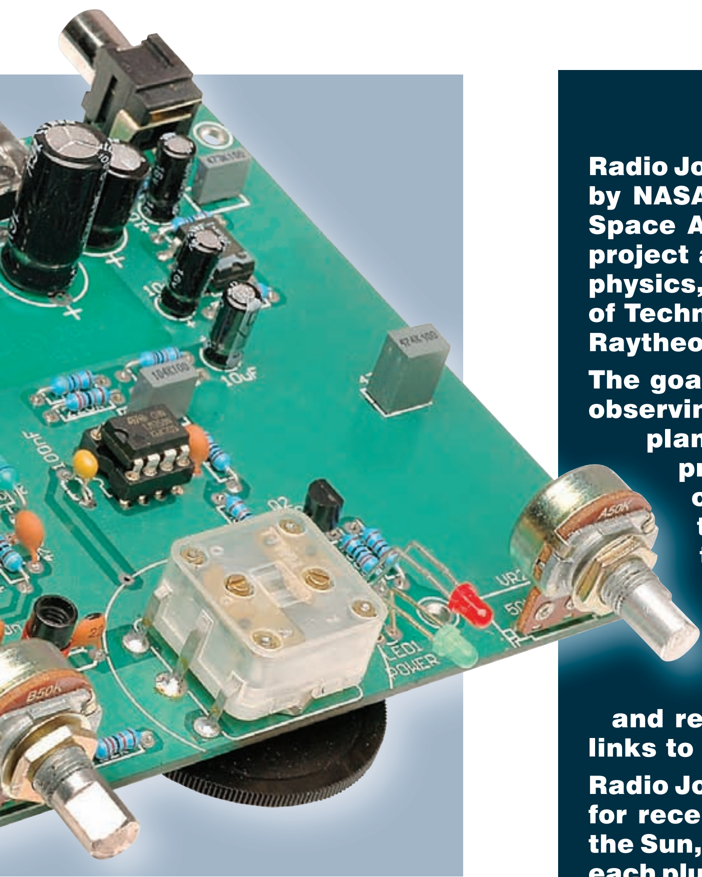
All the input-output connectors are mounted along the rear edge of the board, while the controls and two indicator LEDs are mounted along the front edge. Note that tuning capacitor VC3 (a standard mini 'transistor radio' tuning gang with only one section used) is mounted upside down on the top of the board, with its edgewise tuning knob fitted under the board.

Two 3mm nuts are used as standoffs between the tuning capacitor body and the top of the board, to bring the knob up closer to the board. **This is important if you want to fit the receiver into a low profile instrument case, because the knob will otherwise interfere with the bottom of the case.**

All the components mount on the top of the board, including IC1 and Q1, which are both SMDs (surface-mount devices).

Although you need to be especially careful when fitting IC1 and Q1, building the receiver should be quite straightforward if you work carefully and use the board overlay diagram (Fig.2) and the photos as a guide. Here is the suggested order of assembly:

1) Fit connectors CON1 to CON4 along the rear of the board.
2) Fit the resistors, taking care to fit the correct values in each position.
3) Fit the 8-pin socket for IC2, orientating it as shown to guide you in plugging in the IC later. Note that **a socket is not used for IC3**, as the LM386N is more stable when soldered directly into the board.
4) Now fit IC1 and Q1 to the board, taking the usual precautions with these SMDs. Use an earthed soldering iron with a fine chisel-shaped tip (very clean) and hold each device in position with a wooden toothpick or similar while you apply a tiny drop of solder (tack solder) to the diagonal end pins of the device, to hold it in position while you solder all of the remaining pins.



What Is Radio Jove?

Radio Jove is a radio astronomy education project sponsored by NASA – the US government's National Aeronautics and Space Administration. Other organisations involved in the project are the University of Florida's Department of Astrophysics, the University of Hawaii, Kochi National College of Technology, the INSPIRE Project and companies such as Raytheon, RF Associates and Radio-Sky Publishing.

The goal of Radio Jove is to promote science education by observing and analysing radio signals emanating from the planet Jupiter, the Sun and our Milky Way galaxy. The project is directed primarily at high-school science classes, both in the US and internationally, but interested hobbyists and radio amateurs are welcome to participate.

The Radio Jove project has an office at NASA's Goddard Space Flight Center and also has its own website at http://radiojove.gsfc.nasa.gov.

On this site there are a wide range of resources and reference materials, including observing guides and links to useful secondary sites.

Radio Jove also sells kits for a simple radio receiver suitable for reception of 'decametric' noise signals from Jupiter or the Sun, around 20.1MHz (14.915m). The kits cost US$155.00 each plus shipping (from Greenbelt in Maryland). An assembly manual for the receiver can be downloaded from the Radio Jove website.

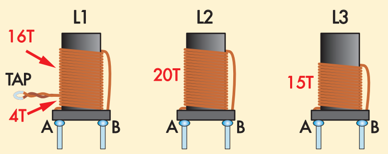
The idea is to make each joint quickly and carefully, using a bare minimum of solder so you don't accidentally bridge between adjoining pins. Also make sure you orientate Q1 correctly; this 4-pin device is very tiny, but its source (S) pin is wider than the other three. **Orientate the device so that this pin is at lower left, and tack-solder this pin first if possible.**

5) Next, fit trimmer capacitors VC1 and VC2, making sure their flat sides face the centre of the board.

6) After these, fit all the smaller fixed capacitors. These are not polarised apart from the 22μF tantalum capacitor, which fits between the 1kΩ and 91kΩ resistors, just to the right of IC1. This capacitor is polarised, so make sure its positive lead is towards the front of the board.

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	2	220kΩ	red red yellow brown	red red black orange brown
❑	1	150kΩ	brown green yellow brown	brown green black orange brown
❑	1	110kΩ	brown brown yellow brown	brown brown black orange brown
❑	1	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	91kΩ	white brown orange brown	white brown black red brown
❑	2	47kΩ	yellow violet orange brown	yellow violet black red brown
❑	1	22kΩ	red red orange brown	red red black red brown
❑	1	10kΩ	brown black orange brown	brown black black red brown
❑	1	2.2kΩ	red red red brown	red red black brown brown
❑	1	1.8kΩ	brown grey red brown	brown grey black brown brown
❑	2	1.5kΩ	brown green red brown	brown green black brown brown
❑	5	1kΩ	brown black red brown	brown black black brown brown
❑	1	820Ω	grey red brown brown	grey red black black brown
❑	1	360Ω	orange blue brown brown	orange blue black black brown
❑	1	300Ω	orange black brown brown	orange black black black brown
❑	1	220Ω	red red brown brown	red red black black brown
❑	1	100Ω	brown black brown brown	brown black black black brown
❑	1	47Ω	yellow violet black brown	yellow violet black gold brown
❑	1	10Ω	brown black black brown	brown black black gold brown



1. BEFORE WINDING EACH COIL, REMOVE ENAMEL FROM END OF WIRE (5mm). THEN TIN AND WRAP IT AROUND TOP OF ONE PIN (A) ON UNDERSIDE OF FORMER. THEN SOLDER.
2. THEN WIND WIRE TIGHTLY AROUND FORMER FROM BOTTOM, WITH TURNS CLOSELY WOUND.
3. WITH L1, WIND 4 TURNS THEN LOOP OUT AND TWIST AS SHOWN TO MAKE 'TAP'. THEN WIND REMAINING TURNS.
4. WHEN ALL TURNS HAVE BEEN WOUND, CUT WIRE ABOUT 13mm FROM END OF LAST TURN. THEN REMOVE ENAMEL FROM LAST 5mm OF WIRE, TIN AND BRING DOWN TO WRAP AROUND TOP OF SECOND PIN (B) ON UNDERSIDE OF FORMER. THEN SOLDER.
5. REMOVE ENAMEL FROM OUTER END OF L1'S TWISTED LOOP 'TAP', THEN TIN SO IT CAN BE SOLDERED TO PAD ON PC BOARD WHEN COIL IS FITTED TO BOARD.

Fig.3: follow these instructions to wind coils L1 to L3.

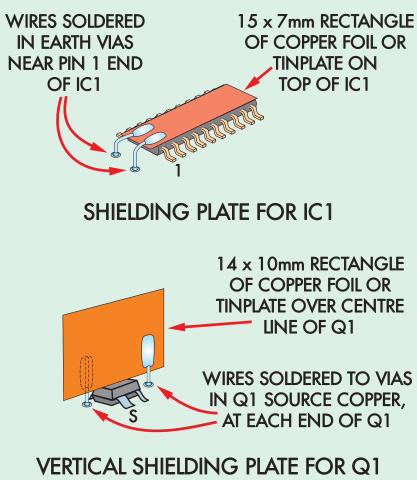
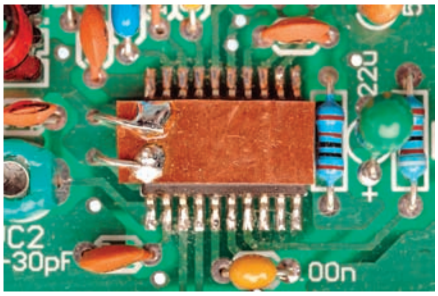
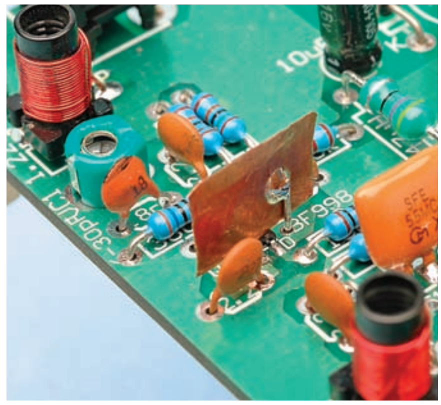


Fig.4: here's how to make and fit the shield plates for IC1 and Q1.

7) Now fit the remaining electrolytic capacitors, which are again all polarised. The correct orientation of each electrolytic capacitor is shown clearly in the overlay diagram.
8) Next, fit RF chokes RFC1 and RFC2, which should both be about 2mm above the PC board.
9) Now fit the two ceramic filters CF1 and CF2, which are not polarised.

These two photos show the shield plates for IC1 (above) and transistor Q1 (right). You can make the shield plates from either copper or tinplate.

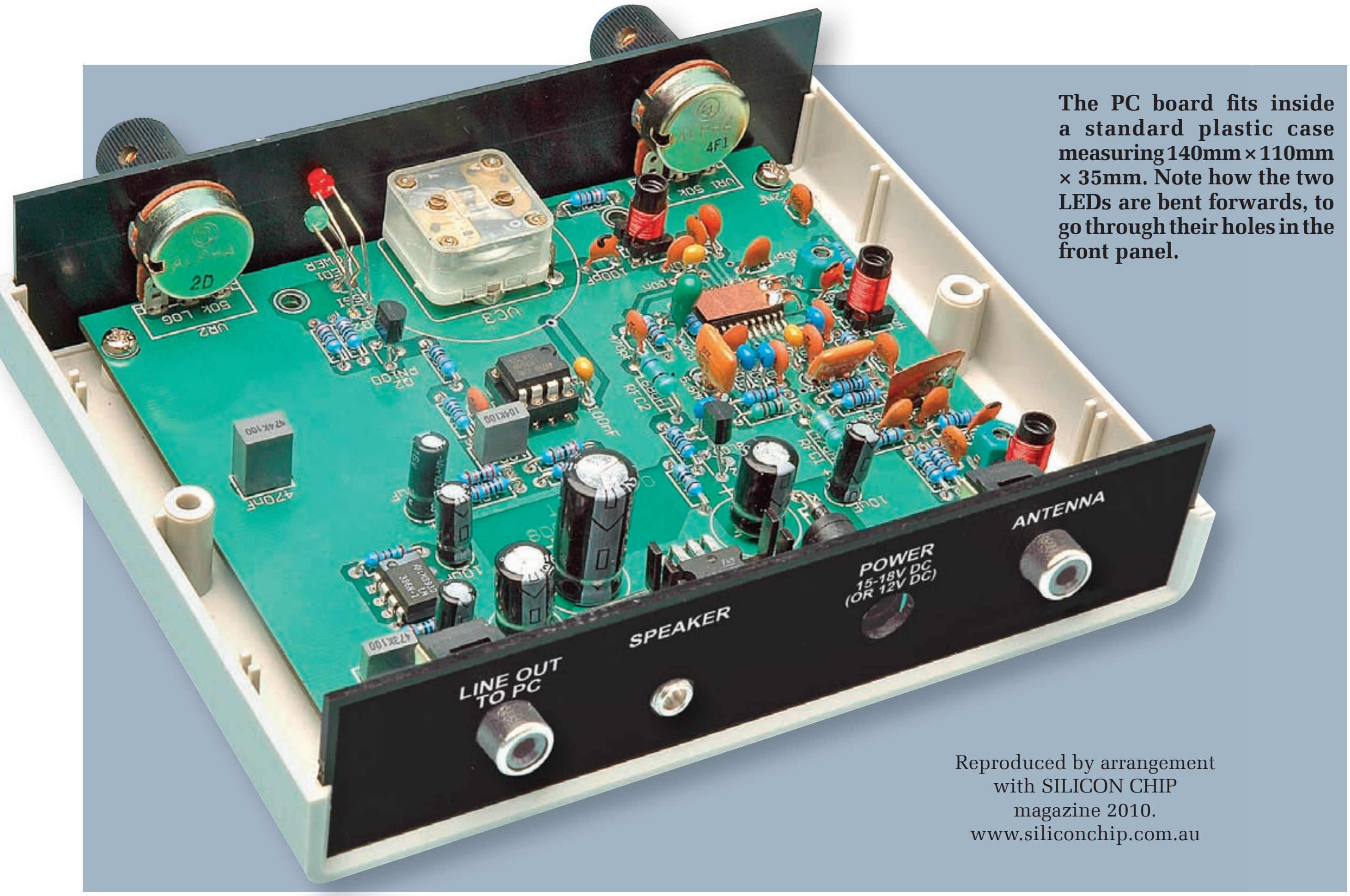
10) Follow with transistor Q2, diode D1, REG2 and LED1 and LED2. Note that the green LED is used for LED1 and the red LED for LED2.
    LED1 is fitted first, with its leads bent down by 90° about 8mm from the body. It's mounted with its body 6mm above the board surface. LED2 is then fitted with its leads bent down about 14mm from the body, so that it sits about 14mm above the PC board.
11) Fit REG1, if you are using it, noting that it is mounted on a small 6093B type finned heatsink. The regulator leads are bent down at 90° 6mm away from the device itself, so they can pass down through the matching board holes. The device and its heatsink are then fastened to the board using an M3 × 6mm screw and nut, after which the leads are soldered to the pads under the board.
12) Fit IC3 directly on the board, orientating it carefully as shown in the overlay diagram Fig.2.
13) Next, fit tuning capacitor VC3. As noted earlier, this fits upside down on the top of the board at centre front, with M3 nuts used as standoffs. The capacitor's tuning knob must be removed from the spindle before it is mounted, and only refitted once the capacitor's leads have been soldered under the board.
14) Fit VR1 and VR2 (the RF and audio gain rotary control pots). These should first have their spindles cut to 10mm long and any burrs removed with a small file. Then each pot is fitted to the board, making sure that you fit the linear (B50k) pot in the VR1 position, and the log (A50k) pot in the VR2 position. Pass their pins carefully through the board holes as far as they'll go comfortably (ie, without undue strain) and then solder them to the pads underneath. Then you can fit the control knobs to the pot spindles.

Tuning coils

15) Wind the three tuning coils L1 to L3. As you can see from the data box in Fig.1, all three coils are wound on 3mm diameter mini coil formers (Jaycar LF-1227, or similar), using 0.25mm enamelled copper wire. In each case, the coils are close-wound at the bottom of the former, as shown in the small diagram of Fig.3.
    Oscillator coil L3 has 15 turns, while the other two have 20 turns each. The difference between L1 and L2 is that L1 has a 'tap' four turns from the bottom.
    This tap is formed from a loop of the winding wire, twisted and tinned at the end so that it can be soldered to the appropriate pad on the PC board (just below CON1) when the coil is fitted. It's a good idea to apply a small amount of clear nail varnish to the upper part of each coil, to hold it in place.
16) When the three coils are completed, they can be fitted to the board. When doing so, make sure you orientate each coil so that its 'A' pin (connected to the bottom of the coil) mates with the earthy or 'colder' pad on the board. The board overlay diagram has a small 'A' next to each coil, to guide you in this regard.

Shield plates

17) Next, you need to make a couple of copper shield plates for IC1 and transistor Q1 to ensure stability.



The PC board fits inside a standard plastic case measuring 140mm × 110mm × 35mm. Note how the two LEDs are bent forwards, to go through their holes in the front panel.

Fig.4 and the photos show how these plates are made and fitted (note: if you are unable to obtain copper foil, you can use tinplate or a piece of blank PC board).

Both shields are attached using short pieces of tinned copper wire which go into adjacent holes in the PC board.

18) Last, plug IC2 (LM358) into its socket, the notched end nearer IC1.

Your Jupiter Receiver board should now be complete and ready for switch-on and set-up.

Setting up

Before applying DC power to the board via CON4, turn both VR1 and VR2 to their fully anticlockwise position. Then plug a small loudspeaker (8Ω) or a pair of stereo headphones into CON3, so you'll be able to monitor the receiver's operation audibly. When you then apply power, very little should happen initially, apart from LED1 beginning to glow.

If LED1 doesn't light, odds are that you've connected the DC supply to the board with the polarity reversed.

Now try turning VR2 (Audio Gain) clockwise slowly. You should begin to hear a gentle hissing sound in the speaker or one of the 'phones. If you have a DMM (digital multimeter), measure the voltage at pin 8 of IC2. It should measure very close to +12V if you're using REG1, or +11.4V if you are powering the receiver from a 12V battery. Now measure the voltage at the rear end of RFC2 (ie, the end nearer REG2) which should be very close to +6V.

Finally, measure the voltage at pin 1 of IC2; this should be quite low – a few tens of millivolts. If you then turn VR1 (RF Gain) clockwise, this voltage should steadily rise due to noise being amplified by Q1, as its gain is increased. The hissing sound in the speaker or 'phone should increase at the same time.

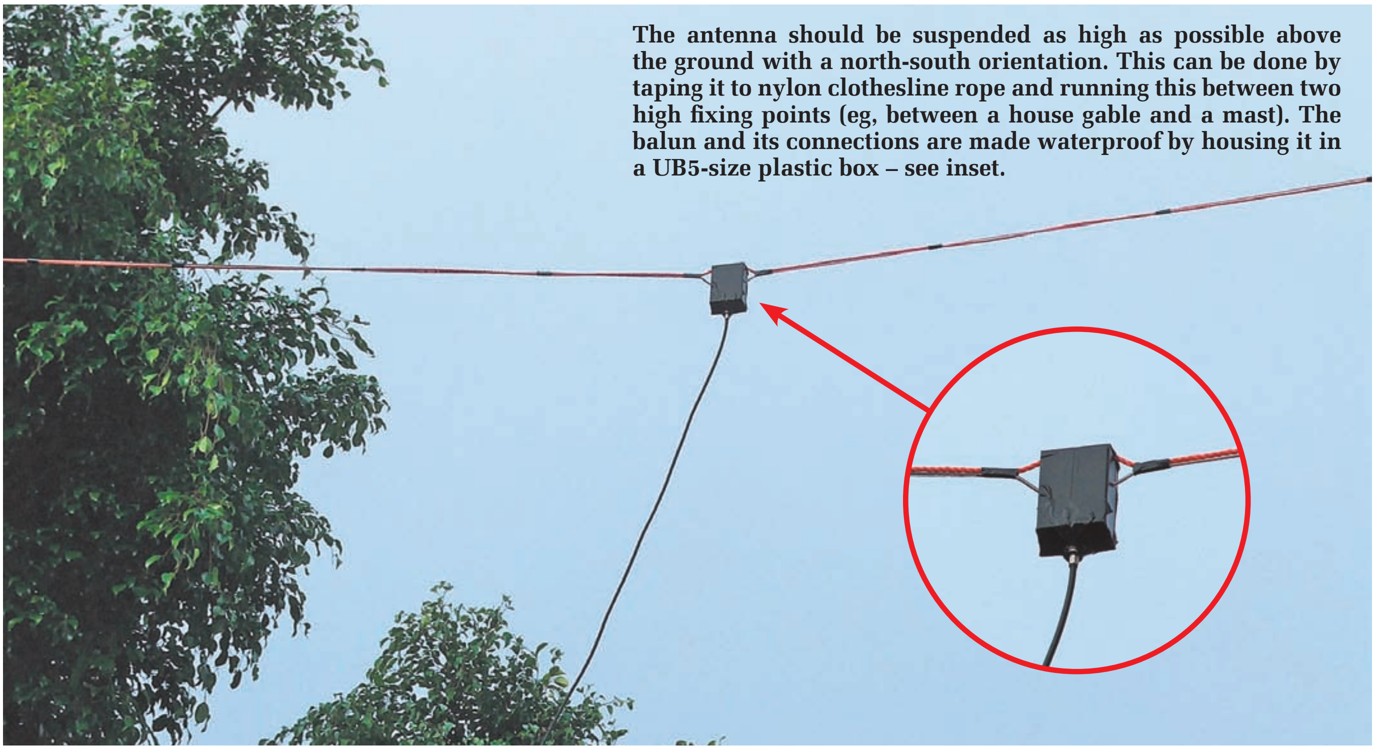
If all is well so far, your receiver is very likely to be working as it should and you'll be ready for setting it up. This mainly involves adjusting trimmer capacitors VC1 and VC2 so that the input and output circuits of the RF stage are tuned to around 21MHz.

The easiest way to do this is if you have access to an RF oscillator or signal generator, able to deliver an amplitude modulated RF signal of 21MHz to the receiver's input. The generator's output is set to a level of about 100mV at first. Then you should turn up both VR1 and VR2 to about the centre of their ranges ('12 o'clock'), after which you can slowly turn the knob of tuning capacitor VC3 up from its lowest setting, until you hear a 400Hz or 1kHz tone (the generator's modulation signal).

Now fine-tune VC3 carefully back and forth with your thumb, to achieve the loudest signal. If the sound becomes too loud or LED2 (the RSSI indicator) begins glowing, turn down VR2 and/or VR1 to reduce the gain. And if the signal is still too loud, try reducing the output level from the RF generator.

Once you are sure that the oscillator is correctly tuned for reception at 21MHz, the next step is to carefully adjust trimmer VC2 with a small alignment tool, to again find the correct position for maximum signal. You may again need to reduce the generator's output level, to prevent overload when you do achieve a peak.

Once the correct tuning position for VC2 has been found, the last step is



The antenna should be suspended as high as possible above the ground with a north-south orientation. This can be done by taping it to nylon clothesline rope and running this between two high fixing points (eg, between a house gable and a mast). The balun and its connections are made waterproof by housing it in a UB5-size plastic box – see inset.

to adjust VC1 in the same way. In this case, you will almost certainly have to reduce the output level from the generator to prevent overload.

In fact, by the time the tuning procedure is finished, the generator's output should be wound down to a mere 1μV or so.

No RF generator

If you don't have access to an RF generator, you'll have to delay this tuning operation until you have built the receiver's antenna, erected it outside in a suitable position and connected it to the receiver's input so that it can provide you with some sort of signal – either a shortwave broadcasting station somewhere in the 20.25MHz to 22.5MHz range, or just some atmospheric noise. More about this shortly, after we've talked about antennas.

Antennas for 21MHz

For reception of noise burst signals from Jupiter or the Sun in the northern hemisphere, the Radio Jove people recommend the use of a twin-dipole antenna array in which two half-wave dipoles are each aligned in an east-west direction and spaced about one half-wave apart, and with both suspended at least 3.6m above ground. The outputs of the two dipoles are combined using a phasing cable arrangement, to tilt the antenna's main receiving lobe towards the south – because currently, Jupiter's orbit is inclined somewhat south of the equator.

In fact, the 'declination' of its highest point ('transit') in moving over the sky varies, but it is currently (summer 2010) rising steadily, and will continue to do so for several years.

However, with our circuit it should be quite feasible to use a basic single-dipole antenna for reception of Jupiter's noise bursts. Accordingly, we have produced and tested the very simple antenna design shown in Fig.5. It consists of a single length of multi-strand copper wire (we used one side of a length of figure-8 speaker cable), cut to a length of 6960mm (6.96 metres) to make it resonant at very close to 21MHz.

This antenna should be suspended at least 3.6m above the ground and aligned as closely as possible to a north-south direction. I did this by taping it to a 6m length of nylon clothesline rope, which was then run between a high point on the gable of my house and the top of a 3m mast, attached to the side of a workshop in the backyard.

To couple signals from the antenna to a cable running back to the receiver's input, I made up a 1:1 balun (balanced to

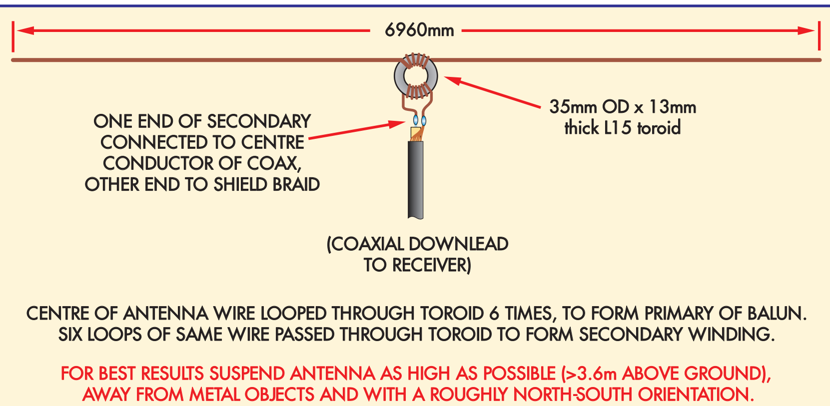


Fig.5: this simple single-dipole antenna can be used with the Jupiter Receiver to receive Jupiter's noise bursts. The dipole is cut to a length of 6960mm to make it resonant at close to 21MHz and is coupled to a coaxial downlead using a simple 1:1 balun made from a ferrite ring toroid.

unbalanced transformer) using a small ferrite toroid as shown. This toroid uses L15 material and is 35mm outside diameter, with a thickness of 13mm (Jaycar LO-1238 or similar). The centre of the antenna wire itself is looped through the toroid six times to form the primary winding of the balun, while a short length of the same type of wire is also looped through the toroid six times to form the secondary winding.

To make the balun weatherproof and secure, it was housed in a little UB5-size plastic box (83 × 54 × 31mm), with the two ends of the antenna wire brought out through a 3mm hole on each side near the top. A BNC socket was then fitted to the lower end of the box, with the ends of the balun secondary winding connected to the socket inside. The downlead cable was connected to the socket on the outside, after the box lid had been screwed on.

The whole thing was then hauled up on the nylon rope (it's very light in weight). I used short strips of gaffer tape to attach the antenna wire and balun to the rope, but nylon cable ties would also be suitable.

A twin dipole antenna?

So how do you choose between a single or twin dipole antenna? There is no question that the single dipole is easier to make and install; on the other hand, the twin is more sensitive. Taking everything into account, it is definitely worth starting off with a single dipole version as described here. However, if you are feeling ambitious, then the twin dipole makes a good addition to this project.

Rather than repeat NASA's Radio Jove material, readers interested in this superior but more complicated approach should go to: **http://radiojove.gsfc.nasa.gov/telescope/ant_manual.pdf** for a full account of the twin dipole design. It also provides useful material on how the declination of Jupiter varies for antennas placed in southern Britain (approx 50° N, and with a little interpolation it is not difficult to estimate it for the rest of Britain, up to approx 55° N.

No-generator tune-up

As mentioned earlier, if you don't have access to an RF oscillator or signal generator it's still possible to tune up the receiver reasonably well once you have an antenna to provide it with some signals in the vicinity of 21MHz.

The way to do this is to connect the antenna, apply power to the receiver and set both VR1 and VR2 to their mid-range (12 o'clock) positions, so you can hear a reasonable level of noise.

Now try adjusting tuning control VC3 very slowly, to see if you can find a shortwave broadcasting station. I found a Chinese station at about 21.68MHz, for example – about two-thirds of the way up the tuning range.

If you do find a station, leave VC3 set to the position for clearest reception and then try adjusting trimmer VC2 very slowly and carefully with a small alignment tool. You should find a position which gives a peak in the signal's reception, but you may need to turn down gain controls VR2 and/or VR1 to lower the volume and prevent overload, so you can accurately find this peak.

Once you are confident that VC2 has been set correctly, leave both VC2 and VC3 with their current settings and turn your attention to VC1, the input circuit trimmer. Again, it's a matter of adjusting this very slowly and carefully until you achieve a signal peak, turning down VR2 and VR1 if necessary to prevent overload and distortion.

What if you can't find a shortwave station to use in the tuning procedure? That needn't be a complete disaster, because if you have a DMM it's possible to use a similar procedure using just the decametric 'cosmic noise' being picked up by the antenna.

To do the tuning this way, set your DMM to a low DC voltage range (say 0V to 2V) and connect it to the receiver to monitor the voltage at pin 1 of IC2. Next, set tuning capacitor VC3 to the centre of its range and gain pots VR1

Decametric Radio Astronomy

BACK IN 1955, US radio astronomers Bernard Burke and Kenneth Franklin discovered that the planet Jupiter was a strong source of 'noise burst' radio signals in the frequency range between about 8MHz and 40MHz – where the radio wavelength is in tens of metres (hence the term 'decametric'). They were using a 'Mills Cross' antenna array, the design of which had been pioneered by Australian radio astronomer Bernard Mills of CSIRO's Division of Radiophysics. The first Mills Cross had been built at Fleurs (about 40km west-south-west of Sydney) the previous year.

It was soon discovered that the Sun itself is also a source of noise bursts during periods of sunspot activity and 'coronal mass ejections' (CMEs). These solar noise bursts extend from the decametric range up to around 80MHz.

The relative ease of receiving noise bursts from Jupiter and the Sun in the decametric frequency range using low-cost equipment seems to be why the Radio Jove project selected this range (rather than in the UHF or microwave regions). It should be noted though that because the signals are broadband in nature, the specific frequency used to receive the signals is not critical. The main requirement is to avoid frequencies occupied by international broadcasters and other terrestrial sources of radio signals.

Useful websites

A great deal of useful information on Jovian and Solar decametric radio astronomy – both theory and practice – can be found on the following websites:

http://radiojove.gsfc.nasa.gov/

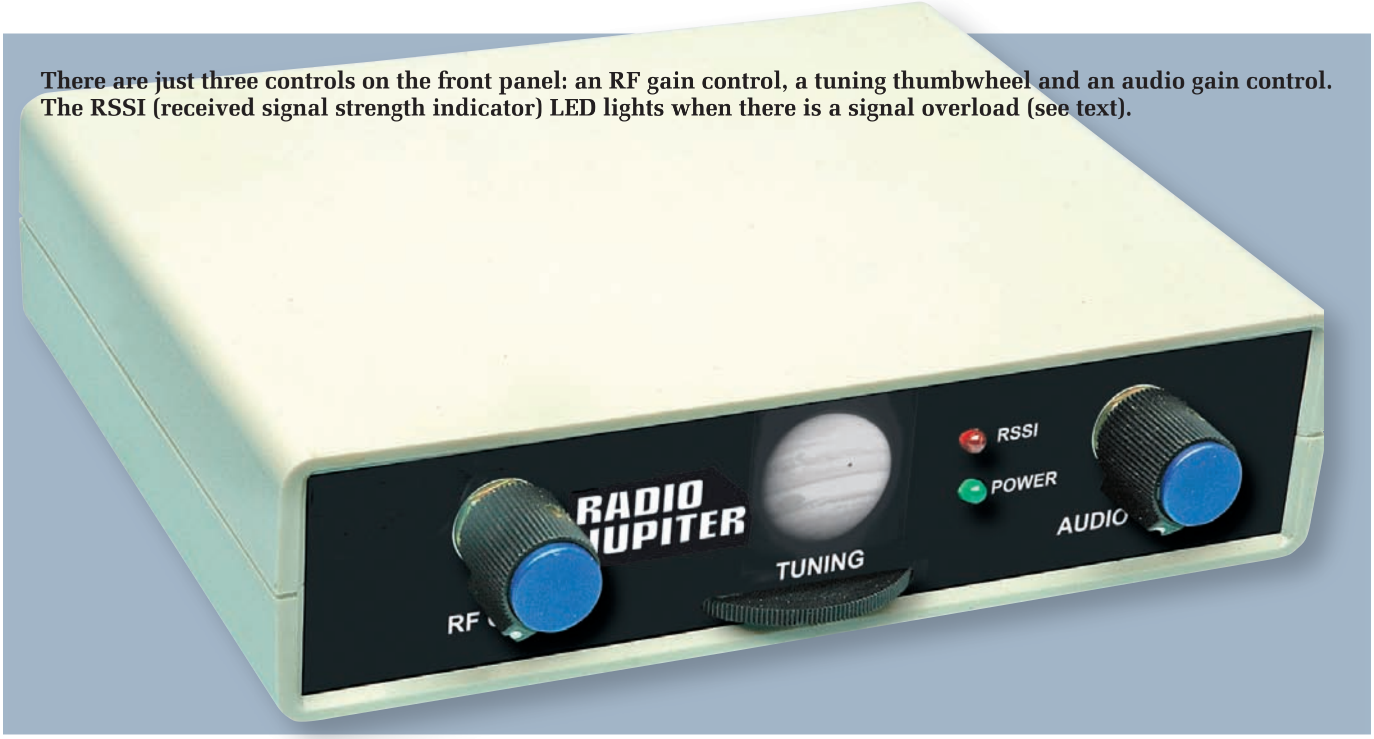
http://ufro1.astro.ufl.edu/dec-contents.htm

http://www.jupiterradio.com/

http://www.radiosky.com/

The last of these sites is the source of the Radio-Skypipe software, which runs on a Windows PC and allows you to record noise data from a Radio Jove or similar receiver and print out 'chart recordings' of them. There is a freeware version of the software that can be downloaded from this site.

A useful source of skycharts and information on the rising and setting times for Jupiter (as well as many other astronomical bodies) in any specific location is: **http://www.heavens-above.com.**



There are just three controls on the front panel: an RF gain control, a tuning thumbwheel and an audio gain control. The RSSI (received signal strength indicator) LED lights when there is a signal overload (see text).

and VR2 to the centre of their ranges as well. When you apply power to the receiver, you should get a reading of 100mV to 200mV or so on the DMM, as well as hearing the received noise in the speaker or 'phone.

Now try adjusting VC2 slowly, first in one direction and then the other, to see if you can increase the DMM reading. Keep turning slowly in that direction, until the meter reading reaches a peak and then begins to drop again. Now return to the position where the reading peaks and leave VC2 in that position.

If the DMM reading rises above about 800mV, lower the RF gain by turning potentiometer VR1 anticlockwise, to bring the reading down again to 200mV. This will make it easier to see the peak reading on the DMM as you adjust VC2.

After VC2 has been set to produce a peak in this way, leave it as before and follow the same procedure with VC1. Again turn down VR1 if necessary to prevent the DMM reading from rising above about 800mV.

Once VC2 and VC1 have been set, your Radio Jupiter receiver should be tuned up about as well as possible without access to a generator.

Fitting it to a case

The PC board is designed to fit inside a low-profile plastic instrument case measuring 140mm × 110mm × 35mm. First, you will have to drill holes in the front and rear panels. Fig.9 and Fig.10 show the front and rear panel artworks, and these can be photocopied and taped to the panels and used as drilling templates.

The board is secured to the two corner pillars at the back of the case using self-tapping screws, while the front of the board is secured to the front panel via the pot shafts and their nuts. **Note that the board sits slightly proud of the front pillars in the case. Don't attempt to screw the board down to these pillars (otherwise the board could crack).**

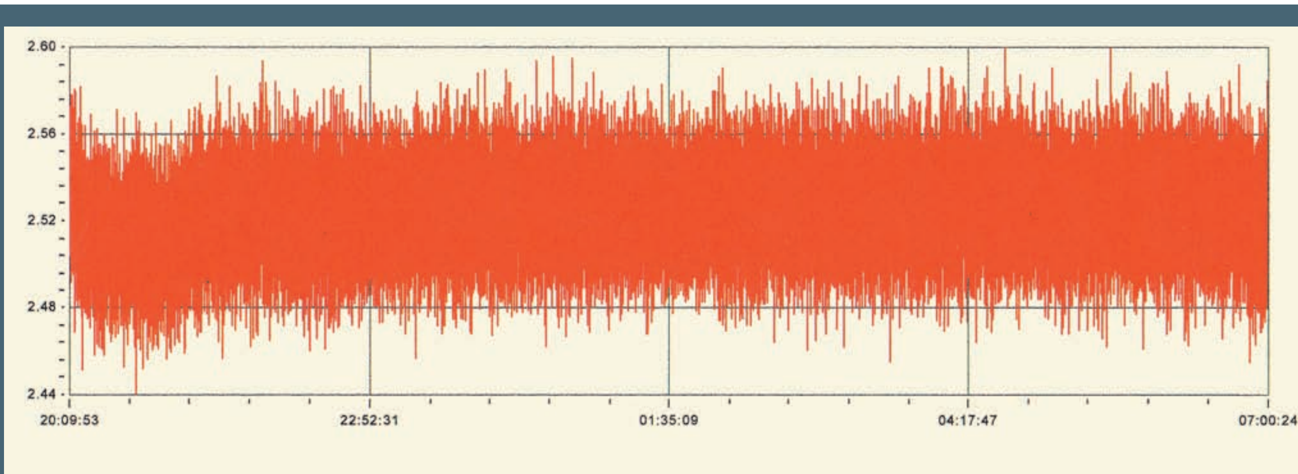
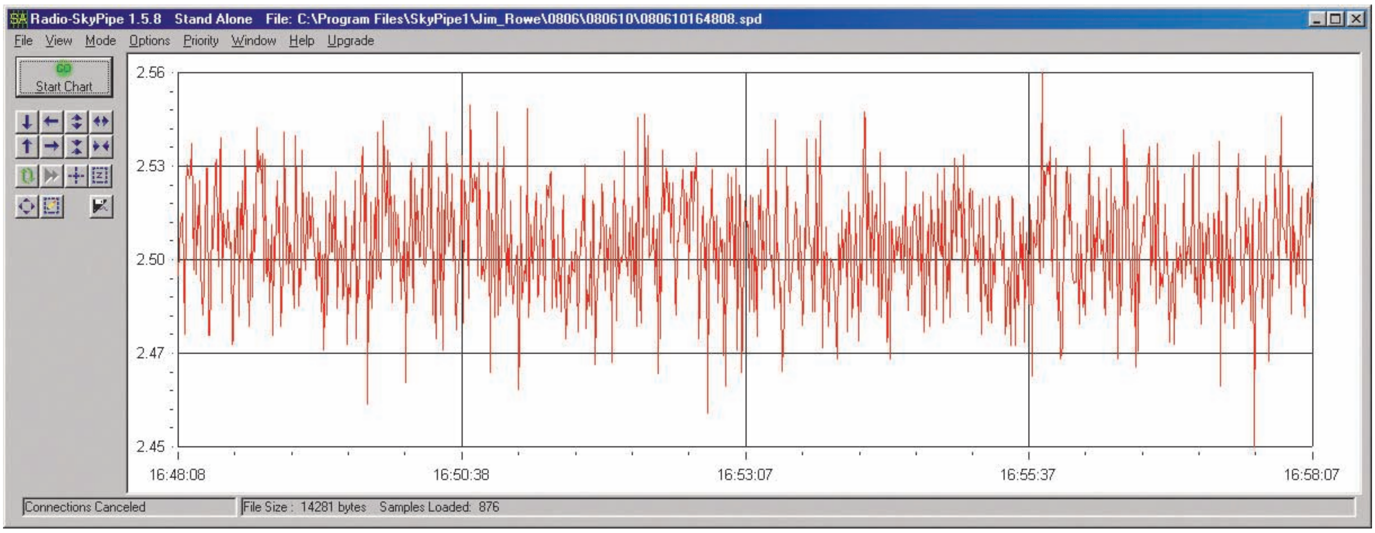


Fig.6: this recording chart covers almost the full period (about 11 hours) of Jupiter's pass on the night of 11 June 2008, but shows very little evidence of signal bursts from Jupiter. Things were quiet around Jupiter that night!



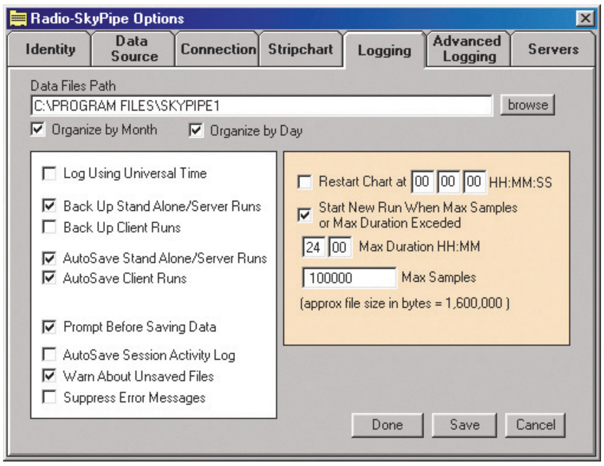


Fig.7 (above): this screen grab from the Radio-Skypipe software shows a recording chart of the 21MHz signal for a 10-minute period.

Fig.8 (left): the Radio-Skypipe software has lots of logging options, including start and logging duration times.

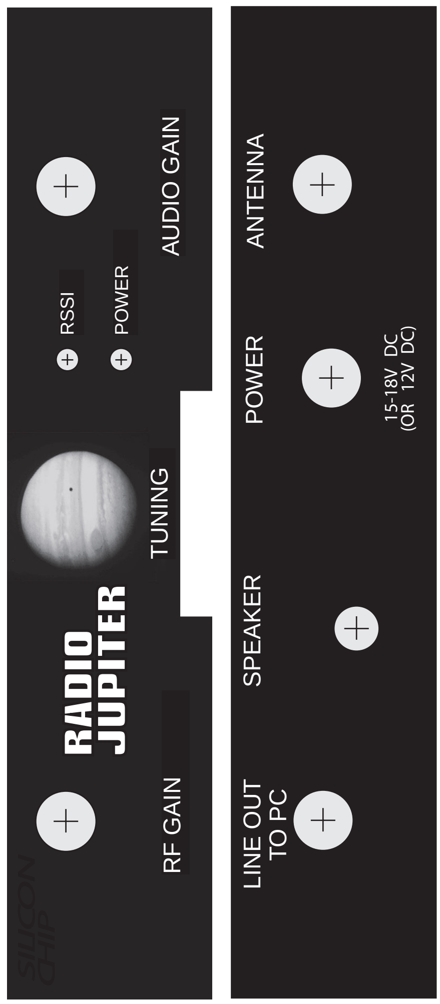


Fig.9: these artworks can be photocopied and used as drilling templates for the case panels.

Testing with Radio-Skypipe

To try out the new receiver and the basic home-brew dipole antenna described earlier, I decided to download a copy of the 'Radio-Skypipe' software, which is recommended by the Radio Jove people. This is a data-logging application which runs under Windows 95/98/NT/2000/XP and can be configured to log data signals via either the ADC (analogue-to-digital converter) in a standard 16-bit PC sound card or an external ADC.

There's a free-download version for non-commercial and non-government users and a Pro Edition with extra bells and whistles available for US$39.95, for commercial and serious users.

I had no trouble installing the Radio-Skypipe software on my old Win98 workshop PC and I was soon using it to take samples of the Jupiter Receiver's audio signal twice every second. It was then left running so that it would log a complete pass of Jupiter over the following night.

When I stopped the logging at 7.00am the next morning, I then saved the log file to the hard disk and was also able to print it out as a pseudo-strip chart recording – see Fig.6.

As you can see, the recording covers almost the full period of Jupiter's pass that night (June 11, 2008), because it rose at about 7pm, reached full transit at 2:07am and set again at around 9am the next morning. But the sky was very overcast that night, so perhaps that's why there's very little evidence of any bursts of signal from Jupiter. Either that, or things were pretty quiet around Jupiter that night.

Looking around for some more information, I discovered that there are two different kinds of decametric noise burst from Jupiter: 'L' or long bursts and 'S' or short bursts. Both seem to be controlled by various factors, including which side of Jupiter is facing our way at the time and also the orbital position of Jupiter's principal moon, Io.

Sunspot and storm activity on the Sun also seem to play a role. They affect the way the Sun sends out streams of charged particles which can spiral around in Jupiter's magnetic field.

So it seems that there probably wasn't much happening around Jupiter the night of my first logging run. The only way to find out is to keep trying, I guess. How about giving it a go yourself? *EPE*

Silly Season

TechnoTalk

Mark Nelson

Summer is traditionally the silly season for the press, so it's only right that Mark should go with the flow. Not all of his stories are daft though, even if it sounds as if he's taking the proverbial mickey.

Regular readers of this column will know I have a weakness for alternative energy sources, from the serious to the sublime. A memorable example of the latter was the NoPoPo (no pollution power) Aqua battery, a reusable AAA or AA-size cell that you activate with beer, apple juice or human urine.

Now a less embarrassing, but equally personal product is the Power Welly. Wearing a pair of 'power wellies', your mobile phone will never die on you, thanks to power-generating soles that convert heat from your feet into electrical current for charging your cellphone tucked into a charging pocket on the thigh part of the boot; apparently.

Wellie-tricity

Twelve hours of aggressive walking is claimed to generate one hour of phone use. The more you exert your feet, the hotter they get, producing more energy. So, power wellies will be fine for farmers and dancers at music festivals, but less beneficial to leisure gardeners. The funny footwear is a product of the amusingly named renewable energy company GotWind (**www.gotwind.org**), where you can see these wacky wellies that were produced in association with mobile phone company Orange.

Andrew Pearcey, Orange UK's head of sponsorship is enthusiastic about this product, which he thought made an ideal fit with the green ethos of the Glastonbury music festival, declaring: 'The Orange Power Wellies use clean and renewable energy to create valuable electricity, ensuring festival goers can text and phone their mates for the duration of the weekend.' Festival-goer Rachel Stone from Southampton endorsed the product, saying: 'These new boots are exactly what I need – my phone never lasts four days.'

Cola-powered phone

An equally way-out British innovation, supported by mobile manufacturer Nokia, is the 'greenphone' designed by Daizi Zheng. Daizi, a graduate of Central St Martin's College in London developed the idea as her final year project: a mobile phone powered by Coca-Cola.

Liquid-infused batteries are by no means new, but this one is alleged to be more effective than previous versions. In fact, it is capable of lasting up to four times longer than a regular lithium-ion battery from a single charge of the drink that 'things' go better with. It generates electricity by using enzymes to catalyse sugar in the drink. It's certainly green in this respect, generating only water and oxygen over and above electricity, although heaven only knows what the environmental cost of producing cola drinks is. The battery itself is attached to the back of the handset, which is a bit awkward, and refilling it looks a bit of a hit and miss affair in the published photographs.

According to *Sky News*, Nokia now considers the phone charging system 'too advanced for immediate development' and has given up on the original idea of bringing out a product within the next two years. Nevertheless, within the next five years, bio-batteries may well be available on the market, as development continues around the world.

Pressure power

As I've said before, some of the most interesting stories get little coverage in the news. Putting this to rights, here's a remarkable tale of a pioneering power plant that in theory at least, is emission-free, renewable and works in all weather conditions (no sun or wind required). The prototype has been quietly in operation since last November and although it currently (no pun intended) generates only enough to heat a large electric kettle (4kW), the aim is to produce enough electricity to light and heat a small town within five years.

The Norwegian organisation that constructed this ultra-green generator is Stakraft, Europe's largest renewable energy company. The group develops and generates hydropower, wind power, gas power, solar power and district heating, and is a major player on the European power exchanges. Its innovative power plant is located at Tofte, outside Oslo, and exploits the commonplace natural mechanism known as 'osmosis'.

In osmosis, water passes through a semi-permeable membrane, which is how plants absorb moisture through their leaves – and prevent it from leaking out. When fresh water meets salt water (for instance where a river runs into the sea), enormous amounts of energy are released. This energy can be utilized for the generation of mechanical power through osmosis.

At the osmotic power plant in Tofte, fresh water and salt water are guided into separate chambers, divided by an artificial membrane. The salt molecules in the sea water pull the freshwater through the membrane, increasing the pressure on the sea water side. The pressure is equivalent to that of a 120 metre water column, or a significant waterfall, which can be used in a power generating turbine.

Research ahead

Statkraft CEO, Bård Mikkelsen declares: 'In an era of major climate change and an increasing need for clean energy, we are proud to be presenting a renewable energy source which has never been harnessed until now.'

Maybe we should be asking why it has not been exploited before and there is certainly plenty of research yet to be done. A major task is creating a membrane of exactly the right thickness, capable of withstanding huge pressures that does not constantly get clogged up with salt.

Right now, the efficiency of the trial set-up is less than $1W/m^2$, but they plan to install membranes that can deliver 2 to $3W/m^2$ after they have run the plant for a while and then reach $5W/m^2$. The prototype station will be in operation for 2 to 3 years. After this the capacity will be increased in stages until ultimately a full-scale osmotic power plant could be built in 2015. At this point, a plant the size of a football stadium could have a capacity of 25MW, enough to supply 30,000 European households.

Statkraft concedes the viability of this technology is unclear, so is osmosis the answer to a maiden's prayer (and everybody else's)? Possibly, the BBC notes that protagonists say the technology has almost unlimited potential, needing just a coastline. Detractors on the other hand claim osmotic power is likely to be prohibitively expensive and argue that tidal power is far more promising as a possible solution for the world's energy problems.

Finally

Going back to the introduction, some people called Michael occasionally take offence at the expression 'taking the mick' or 'taking the Michael', without realising the saying has an entirely different origin. According to the BBC website, and many other normally reliable sources, it's an abbreviation of 'taking the micturition'. Micturition is a medical word and you will probably not be very surprised when you look up its meaning in a dictionary.

Wikipedia has an alternative derivation, from Cockney rhyming slang, 'taking the Mickey Bliss'. The oddest thing is that the Oxford English Dictionary traces 'taking the mike' back to 1935, whereas the cruder 'taking the ****' does not appear in print until 1945. However, this may be simply because past generations (like me) were too polite to use four-letter words in print.

Ultra-LD 200W Power Amplifier

All the assembly details plus building a power supply

Last month, we introduced our new Ultra-LD 200W Amplifier module and described the circuit. This month, we give the assembly details and describe a suitable power supply.

THIS NEW 200W audio amplifier module gives superlative performance – better than any of our previous class-AB amplifiers. That's been made possible by the use of On Semiconductor's new ThermalTrak power transistors, a circuit based largely on our high-performance Class-A Amplifier (published in 2008/09) and a new double-sided PC board.

As mentioned last month, the double-sided PC board is critical to the performance of this amplifier module. It not only simplifies the supply wiring, but has also been designed to largely cancel the magnetic fields produced by the asymmetric currents drawn by each half of the class-B output stage.

The assembly is really quite straightforward, although there's a fair bit of work involved to do the job properly. When building a high-power amplifier module like this, it's important to take your time, do a neat job and check your work carefully at each assembly stage. After all, blowing up expensive output transistors can be a real pain.

Transistor quality

We'll begin the assembly details shortly, but first a word about the transistors used in this module.

To ensure published performance, the NJL3281D and NJL1302D power transistors must be On Semiconductor branded parts, while the 2SA970 low-noise devices must be from Toshiba. Be wary of counterfeit parts (although it's probably too early for counterfeit versions of the power output devices).

We recommend that all other transistors used in this project be from

Part 2: By JOHN CLARKE and GREG SWAIN

reputable manufacturers, such as Philips (NXP Semiconductors), On Semiconductor and ST Microelectronics. This applies particularly to the MJE15030 and MJE15031 output driver transistors.

Circuit board

Fig.9 shows the parts layout on the amplifier double-sided PC board. This board is coded 767 (Amp) and measures 135mm × 115mm. It is available from the *EPE PCB Service*. The orange tracks and pads show the copper on the top of the board, while the blue-grey tracks are on the underside of the board.

The first thing to note is that the PC pattern differs slightly from that used for the prototype module. That's because we subsequently decided to increase the number of vias used to link the top and bottom supply rail tracks. Up to 4.5A peak can flow through each output transistor when the module is operated into a 4Ω load, so it's important to ensure sufficient current-carrying capability.

However, the main reason for increasing the number of vias was to make sure that a fault in the output stage would not cause the vias to fuse, instead of the 5A fuses blowing. If that happened, the board would be difficult to repair, as the solder mask goes right up to the edges of the vias.

As a result, we've increased the number of parallel vias in the high-current paths, generally grouping them together in patterns of five or more (so that they look like the face of a dice). Note, that unlike the outer vias, the middle via of each group of five has a solder pad on both sides of the board. This allows a tinned copper wire 'feed-through' to be fitted to each of these middle vias and soldered in place.

These tinned copper wire feed-throughs ensure that the vias cannot possibly fuse in the event of an output stage fault. They also ensure very low resistance between the top and bottom track sections.

We've also added extra vias to connect the low-current signal tracks on both sides of the PC board, in the interests of redundancy. This is a 'belts 'n braces' measure, but it is still good practice.

Finally, a 390Ω 1W resistor was added to the board to provide the headphone output. As part of this change, CON3 was changed from a 2-way terminal block to a 3-way terminal block to give the 'Phones Out' terminal (note: these changes are not shown on the photos). A few minor changes were also made to improve component fit.

Board assembly

All spare holes on the double-sided power amp PCB need to be 'pinned' through to the underside to achieve connections on both sides. You can use off cuts from component leads or pre-tinned copper wires. Some components need soldering on both sides of the PCB. Fig.9 shows the assembly details. Begin by installing the tinned copper wire feed-throughs to the pads of each group of five vias. It's simply a matter of pushing a wire through each via and soldering it on one side. When you do this, the solder should run inside the via and onto the solder pad on the other side of the board.

> **WARNING!**
>
> High AC and DC voltages are present on the power supply and power amplifier modules when power is applied. **In particular, make sure you don't come in contact across the two 40V AC input terminals on the power supply. The 40V AC transformer windings that connect to these terminals are wired in series, so there's 80V AC between them.**
>
> Similarly, note that **there is 110V DC between the +55V and –55V supply rails**, both on the power supply module and the amplifier module. Do not touch any of this AC or DC supply wiring (including the fuseholders) when the amplifier is operating, otherwise you could get a very nasty shock which could even prove fatal.

If not, solder it on the other side of the board as well, then cut the wire off short on both sides of the board.

Note that it isn't really necessary to fit feed-throughs to the vias immediately below the fuseholders, since the fuseholder pins themselves act as feed-throughs. However, they can be installed if you wish. Don't forget the via that sits under the two 0.1Ω resistors at top left.

Once the feed-throughs are in, install the two 1N4148 diodes (D1 and D2), followed by the resistors (but not the 5W types) and the capacitors. The resistor colour codes are shown in Table 1, but we strongly advise that you also check each value using a digital multimeter before it is installed. Mount them so that they all face in the same direction, to facilitate checking later on.

Make sure that the diodes and electrolytic capacitors are all installed with the correct polarity. If you make a mistake, it's not as easy to remove a component from a double-sided board as it is from a single-sided board. It can

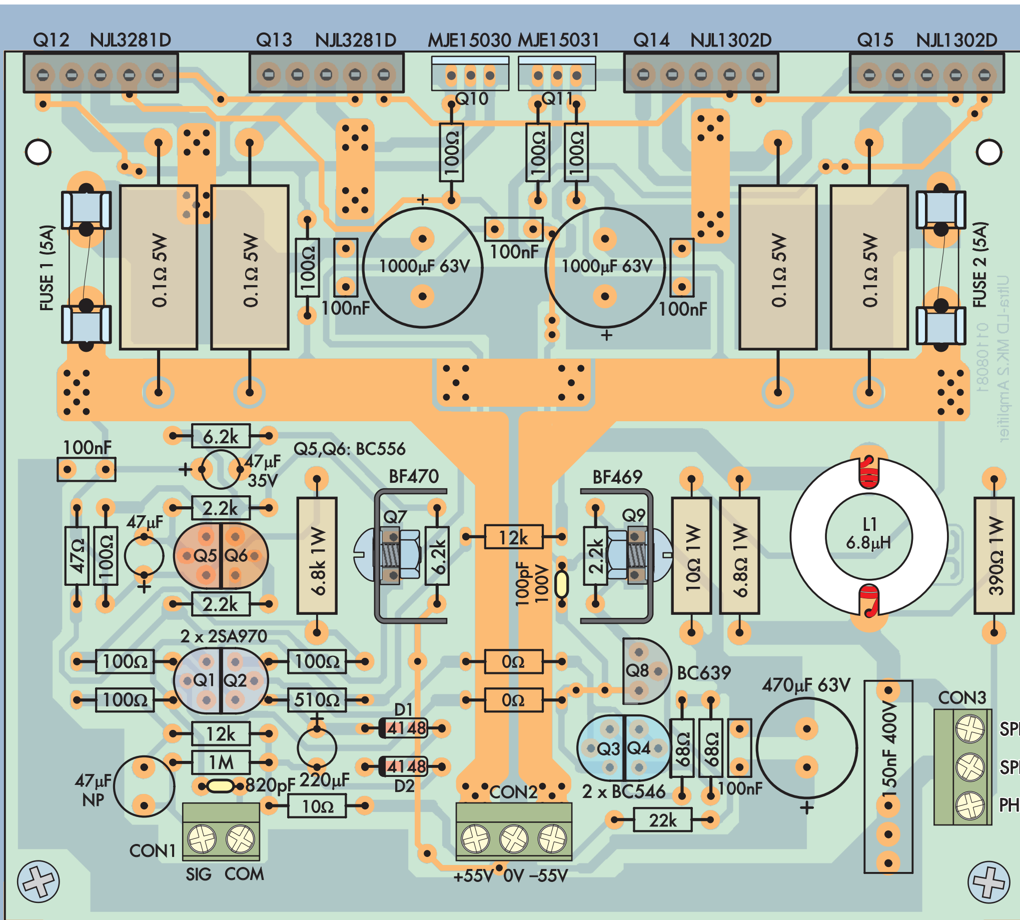


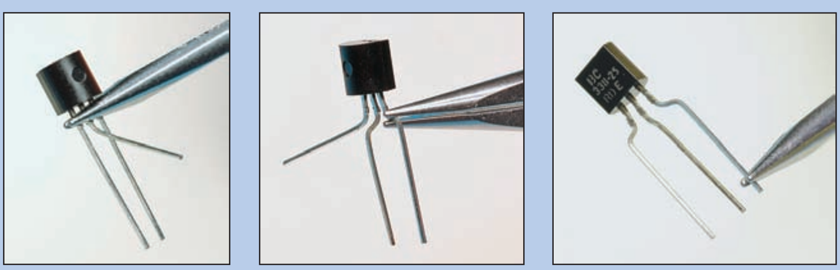
Fig.9: follow this component layout diagram and the instructions in the text to build the Ultra-LD Amplifier module. Note that you should install a tinned copper wire feed-through wherever there's a via with a solder pad, typically in the middle of each group of five vias.

be done, although you usually have to sacrifice the part – see the panel headed 'Removing parts from the PC board' for details on removing components.

We suggest that you leave the two 1000µF electrolytic capacitors off the board for the time being, as this makes it easier to secure transistors Q10 and Q11 to the heatsink later on. Even with the capacitors in place, you still have good screwdriver access to these transistors. However, there's a risk that one of these capacitors could be damaged if the screwdriver slips while doing up the mounting screws.

Note that the 100pF capacitor on the collector of transistor Q9 should be rated at 100V. Alternatively, use a 3kV type.

Now install the four 0.1Ω 5W resistors. These have their leads bent down through 90° some 5mm from their bodies, and should be mounted about 1.5mm above the surface of the PC board to allow air to circulate beneath them for cooling.



The leads of the TO-92 transistors should be cranked to fit their mounting holes in the PC board using a pair of needle-nose pliers. Here's how it's done.

The easiest way to do this is to use a strip of cardboard about 20mm wide and 1.5mm thick as a spacer. You simply push the resistor all the way down onto the cardboard, solder the leads, then pull the cardboard back out.

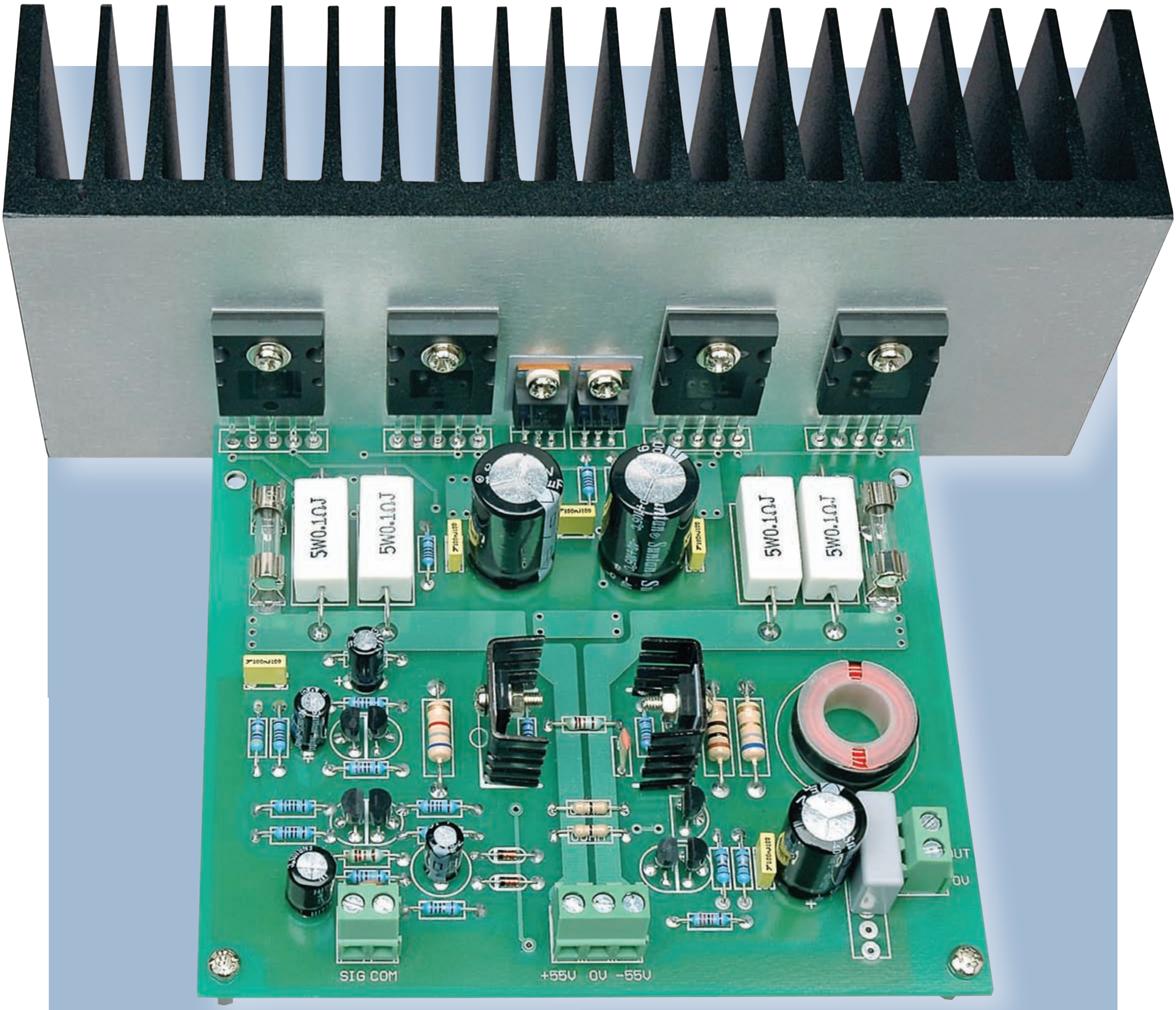
Mount the 5W resistors with their values all facing up and reading in the same direction. Again, this makes it easier to check them later on.

The fuse clips are next on the list. Note the each fuse clip has a little lug on one end which stops the fuse from moving lengthways. If you install the clips the wrong way round, those lugs will stop you from fitting the fuses.

It's a good idea to use sticky tape to hold the fuse clips in place while you solder their leads. This same trick is also useful when it comes to mounting some of the other parts, such as the screw terminal blocks.

Small signal transistors

The small-signal (TO-92 package) transistors (2SA970s, BC546s,



This prototype module differs slightly from the version shown in Fig.9. Take care to ensure that all transistors go in their correct locations and are correctly orientated. It's a good idea to slightly splay the bottom fins of the heatsinks fitted to Q7 and Q9, to increase the clearance to the solder pads of the adjacent 6.2kΩ and 2.2kΩ resistors.

BC556s and BC639) can now go in. As supplied, these transistors usually have their leads in a straight line, although the centre lead may sometimes be cranked out. These leads should be splayed outwards and cranked to fit nicely into their allocated holes.

The best way to do this is as follows: first, grip the three leads adjacent to the transistor body using a pair of needle-nose pliers and bend the centre lead back and up by about 70° (if it hasn't already been cranked). That done, grip each of the two outer leads in turn and bend them outwards and up by about 70°. Finally, grip each lead in turn at the end of the pliers and bend it downwards again – see photos.

Install each transistor after dressing its leads. If the leads are dressed correctly, the transistors will each sit about 4mm proud of the PC board. Note that transistor pairs Q1 and Q2, Q3 and Q4, and Q5 and Q6 are installed with their flat sides facing each other.

Make sure that you don't install these transistors in the wrong positions. Inadvertently swapping 2SA970s for BC556s will cause problems (even though they are both *PNP* types) because their pinouts are different. Similarly, swapping BC546 *NPN* transistors for BC556 or 2SA970 *PNP* types could cause serious damage when the amplifier is powered up. You have been warned!

The TO-126 package transistors, Q7 and Q9, are fitted to TO-220 U-shaped mini finned heatsinks *before* they are soldered to the PC board. The best approach is to first loosely attach one transistor to the inside face of its heatsink using an M3 × 10mm screw, nut and two flat washers – see Fig.10. The assembly is then fitted in position and pushed

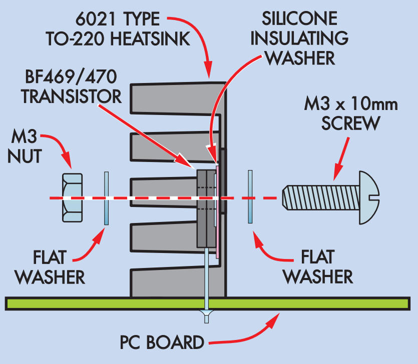


Fig.10: follow this diagram to attach the BF469 and BF470 transistors to their respective heatsinks. The silicone insulating washer is optional, but it's not a bad idea to isolate the heatsinks from the transistor collectors to prevent accidents when testing.

all the way down until the heatsink contacts the PC board.

That done, the transistor's leads are soldered and the heatsink mounting screw tightened. As with the fuse clips, you can use some sticky tape to hold the assembly in place while the leads are soldered. It's best to lightly solder one lead first and then make any adjustments that may be necessary before soldering the other two leads.

Repeat this procedure for the other transistor. Be sure to use a BF470 (*PNP*) transistor for Q7 and a BF469 (*NPN*) for Q9. Don't get them mixed up, otherwise the smoke will get out when you apply power!

It's important to centre these heatsinks so that their fins cannot contact the solder pads of the adjacent 6.2kΩ and 2.2kΩ resistors (splay the bottom fins of each heatsink slightly if necessary). If you're cautious, you can fit TO-126 silicone insulating washers to isolate the collectors of the transistors from the heatsinks (we did this to avoid accidents with test probes while testing the prototype). However, provided you centre the heatsinks correctly, it's not really necessary.

Winding the choke

The next step is to wind the 6.8µH inductor (L1). This is done by close-winding about 1.5m of 1mm-diameter enamelled copper wire onto a plastic bobbin Jaycar LF-1062). This bobbin can have an inside diameter of either 10mm or 11.8mm (OD = 20mm or 21mm).

It order to do a neat job, it's necessary to make a small winding jig to hold the bobbin. This jig not only prevents the bobbin from being damaged, but also makes the job much easier. The accompanying panel ('Making A Winding Jig For The 6.8µH Inductor') shows how the winding jig is made.

Once you have the jig, begin the winding by feeding about 40mm of the wire through one of the bobbin slots and the exit hole in the jig (loosen the handle if necessary to do this). Bend this end back through 180° to secure it, then tighten the handle and wind on 25.5 turns as evenly and tightly as possible. Finish by bending the remaining wire length through 90° so that it exits down through the opposite slot.

The windings are now secured using a couple of layers of insulation tape and the bobbin removed from the jig. That done, cut off the excess leads at each end, leaving about 10mm protruding.

Finally, complete the inductor by fitting some 20mm-diameter (9mm wide) heatshrink tubing over the windings. Be careful when shrinking it down with a hot-air gun though – too much heat will damage the bobbin.

You can now test fit the finished inductor on the PC board, bending its leads as necessary to get the bobbin to sit down flush on the board. It's then just a matter of stripping the enamel from the wire ends and 'tinning' them before soldering the inductor in place.

Heatsink transistor mounting

As shown in the photos, the driver and output transistors (Q10 to Q15) are all mounted on a large finned heatsink measuring 200 × 75 × 48mm (L × H × D); eg, Jaycar HH-8546.

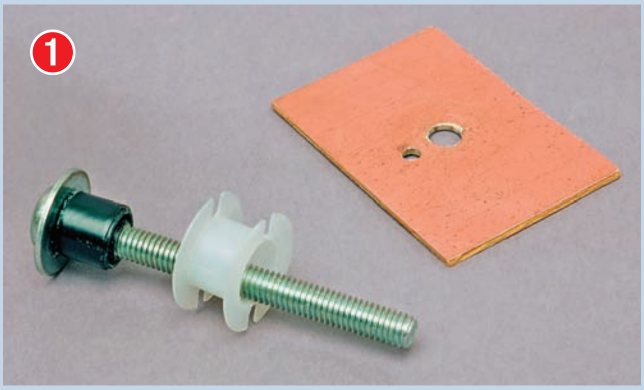
You've got two choices when it comes to mounting these transistors: (1) drill 3mm holes right through the back of the heatsink and attach the transistors using M3 screws, nuts and washers; or (2) drill and tap mounting holes and attach the transistors using M3 screws and washers.

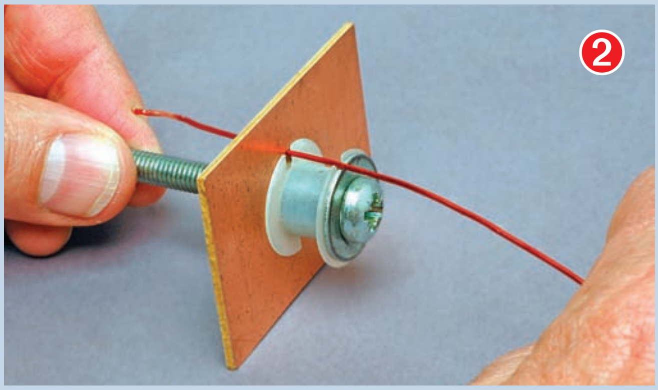
Drilling the holes right through the heatsink is the easiest option, but note that you will have to offset the module horizontally by 10mm towards one end so that the holes go between the heatsink fins. Alternatively, if you elect to tap the heatsink, the module can be centred horizontally. This method also makes it easier to install the mounting screws.

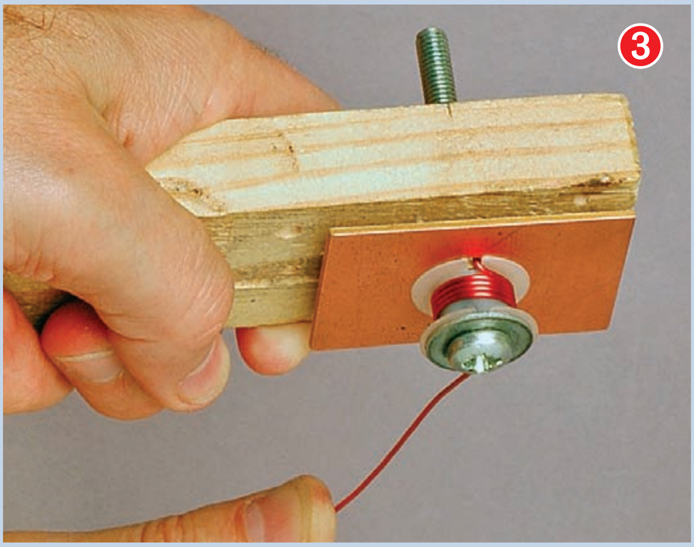
Table 1: Resistor Colour Codes

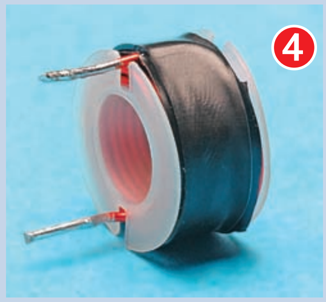
❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	1	1MΩ	brown black green brown	brown black black yellow brown
❏	1	22kΩ	red red orange brown	red red black red brown
❏	2	12kΩ	brown red orange brown	brown red black red brown
❏	1	6.8kΩ 1W 5%	blue grey red gold	not applicable
❏	2	6.2kΩ	blue red red brown	blue red black brown brown
❏	3	2.2kΩ	red red red brown	red red black brown brown
❏	1	510Ω	green brown brown brown	green brown black black brown
❏	1	390Ω	orange white brown brown	orange white black black brown
❏	8	100Ω	brown black brown brown	brown black black black brown
❏	2	68Ω	blue grey black brown	blue grey black gold brown
❏	1	47Ω	yellow violet black brown	yellow violet black gold brown
❏	1	6.8Ω 1W 5%	blue grey gold gold	not applicable
❏	1	10Ω	brown black black brown	brown black black gold brown
❏	1	10Ω 1W 5%	brown black black gold	not applicable
❏	4	0.1Ω	not applicable	not applicable
❏	2	0Ω	black	black

Making A Winding Jig For The 6.8μH Inductor









These photos show how the winding jig is used to make the 6.8μH inductor. First, the bobbin is slipped over the collar on the bolt (1), then an end cheek is attached and the wire threaded through the exit slot (2). The handle is then attached and the coil tightly wound onto the bobbin using 25.5 turns of 1mm-diameter enamelled copper wire (3). The finished coil (4) is secured using a couple of layers of insulation tape and a band of heatshrink tubing.

The winding jig consists of an M5 × 70mm bolt, two M5 nuts, an M5 flat washer, a piece of scrap PC board material (40 × 50mm approx.) and a scrap piece of timber (140 × 45 × 20mm approx.) for the handle.

In use, the flat washer goes against the head of the bolt, after which a collar is fitted over the bolt to take the bobbin. This collar should have a width that's slightly less than the width (height) of the bobbin and can be wound on using insulation tape.

Wind on sufficient tape so that the bobbin fits snugly over this collar without being too tight.

Next, drill a 5mm hole through the centre of the scrap PC board material, followed by a 1.5mm exit hole about 8mm away that will align with one of the slots in the bobbin. The bobbin can be slipped over the collar, after which the scrap PC board 'end cheek' is slipped over the bolt (ie, the bobbin is sandwiched into position between the washer and the scrap PC board).

Align the bobbin so that one of its slots lines up with the exit hole in the end cheek, then install the first nut and secure it tightly. The handle can then be fitted by drilling a 5mm hole through one end, then slipping it over the bolt and installing the second nut.

The heatsink drilling details are shown in Fig.11. You should also refer to the accompanying panel for information on drilling and tapping aluminium, since there are some special techniques to be followed if the job is to be a success.

We'll assume here that you've tapped the heatsink, ie, by drilling and tapping the white holes marked 'A' on Fig.11.

Begin the heatsink assembly by attaching the two driver transistors, Q10 and Q11. Fig.12 (A) shows the mounting details for these devices.

Note that they must each be electrically insulated from the heatsink using a TO-220 silicone insulating washer and insulating bush. However, because Q10 and Q11 are quite close together, it's necessary to trim about 1mm off the adjacent sides of each insulating washer so that they don't overlap.

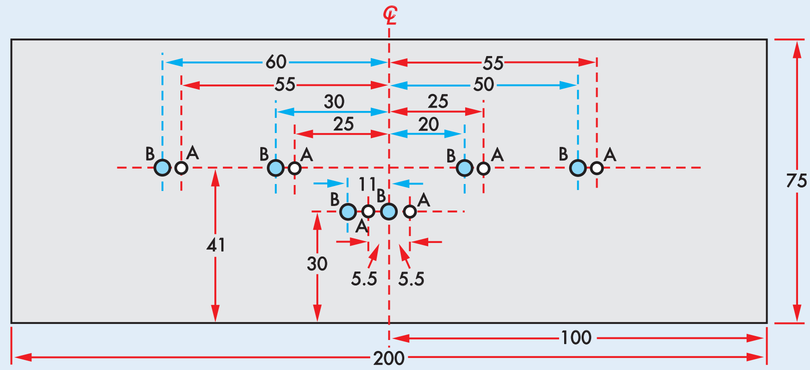
Use an MJE15030 for Q10 and an MJE15031 for Q11 – don't get them mixed up. Both devices are secured using an M3 × 6mm screw and an insulating bush. Do the screws all the way up, but don't tighten them yet.

Next, fit a 10mm spacer to each of the four corner mounting positions on the PC board. When they're on, sit the board assembly on a flat surface and then lower the heatsink assembly into position so that Q10 and Q11's leads go through their mounting holes.

Power transistor mounting

The four output devices (Q12 to Q15) can now be fitted. **As shown in**

Drilling and tapping the aluminium heatsink



HOLES A: DRILL 2.5mm DIAMETER, TAP FOR M3 SCREW   HOLES B: DRILL 3.5mm DIAMETER   (SCALE 1/2)

Fig.11: this half-size diagram shows the drilling details for the heatsink. For tapped holes, mark out and drill the white holes marked 'A' to a depth of 7mm (2.5mm drill, M3 tap). Alternatively, if you intend drilling right through the heatsink, drill the blue holes marked 'B' (3.5mm drill).

FIG.11 (above) shows the heatsink drilling details. The white holes are drilled if you intend tapping the holes, while the blue holes are drilled if you want to drill right through the heatsink (ie, between the fins).

If you intend drilling right through the heatsink, simply mark out the blue hole locations using a sharp pencil, then accurately drill the holes **using a drill press.** Use a pilot drill to begin with – the holes have to go between the fins so it's vital to accurately position them.

Be sure to use a suitable lubricant when drilling the holes. Kerosene is the recommended lubricant for aluminium, but we found that light machine oil (eg, Singer) also works well for jobs like this.

Don't try drilling the holes in one go. **When drilling aluminium, it's important to regularly remove the bit from the hole and clear away the metal swarf.** If you don't do this, the aluminium has a habit of migrating onto the drill bit and ruining it.

Don't even think of using a hand-drill for this job by the way. There's no way you'll get the holes perfectly perpendicular to the mounting face.

Once the holes have been drilled, deburr them using an oversize drill to remove any metal swarf from the mounting surface. This is vital to prevent punch-through of the insulating washers.

Finally, the heatsink should be thoroughly scrubbed cleaned using water and detergent and allowed to dry.

Drilling and tapping

Alternatively, if you want to centre the module horizontally on the heatsink, you will have to drill and tap holes to accept M3 screws in the locations shown (ie, the white holes). This method is more time-consuming than drilling right through, but it does make it easier to mount the transistors when it's done.

To do the job, you will need a 2.5mm drill, an M3 intermediate (or starting) tap and an M3 finishing tap. If you are unable to obtain a finishing tap, you can make one by grinding most of the tapered end off an intermediate tap.

The first step is to mark out and drill the mounting holes to a depth of exactly 7mm using a 2.5mm drill. **As before, be sure to regularly clear the hole and the drill bit of any metal swarf and keep the drill bit well-lubricated.**

Once the holes have been drilled, tap each one in turn, starting with the M3 intermediate tap and then finishing with the M3 finishing tap. The trick here is to take it nice and slowly. **Keep the lubricant up and regularly wind the tap out to clear the metal swarf from the hole.**

You will know when you're coming to the end of the hole by the increased resistance to turning the tap handle. Do not at any stage apply undue force to the tap. It's easy to break a tap in half and if the break occurs at or below the heatsink's face, you can scratch both the tap and the heatsink (and about £15).

As before, deburr the holes using an oversize drill and scrub the heatsink clean using water and detergent. Make sure that the mounting surface is perfectly smooth before installing the heatsink transistors.

Fig.12 (B), these devices must also be insulated from the heatsink by using silicone insulating washers.

Start by fitting Q12. The procedure here is to push its leads into their PC mounting holes, then lean the device back, feed through the mounting screw, hang the insulating washer off the end of the screw and finally, loosely screw the assembly to the heatsink.

The remaining three devices are installed the same way, taking care to fit the correct transistor type at each location. Once they're in, push the board down so that all four spacers are in contact with the benchtop – this automatically adjusts the transistor lead lengths and ensures that the bottom of the board sits exactly 10mm above the bottom edge of the heatsink.

Now adjust the PC board assembly horizontally so that each side is 32.5mm in from its adjacent heatsink end, then do up the transistor mounting screws while keeping the insulating washers correctly aligned.

The next step is to lightly solder the outside leads of Q12 and Q15 to their pads on the top of the board. The assembly is then turned upside down and the remaining heatsink transistor leads soldered.

Before soldering the leads though, **it's important to prop the front edge of the board up so that the board sits at right-angles to the heatsink.** If you don't do this, it will sag under its own weight and will remain in this condition after the leads have been soldered.

Complete the soldering, then turn the board right way up again and tighten down the transistor mounting screws. They should be tight to ensure good thermal coupling between the devices and the heatsink.

Checking device isolation

Now check that each device is indeed electrically isolated from the heatsink. That's done by switching your multimeter to a high ohms range and checking for shorts between the heatsink mounting surface and the collectors of the heatsink transistors (note: the collector of each device is connected to its metal face or tab).

In practice, it's simply a matter of checking between the fuse-clips closest to the heatsink and the heatsink itself. That's because the device collectors in each half of the output stage are connected together and run to their respective fuseholder.

In each case, you should get an open-circuit reading. If you do find a short, undo each transistor mounting screw in turn until the short disappears. It's then simply a matter of locating the cause of the problem and remounting the offending transistor.

Be sure to replace the insulating washer if it has been damaged in any way (eg, punched through).

Completing the assembly

The assembly can now be completed by installing the two 1000µF 63V capacitors and the three screw terminal blocks (CON1 to CON3). Take care when installing the latter – the access holes must face outwards.

You should also remove the two support spacers from the edge of the board adjacent to the heatsink. **In fact, it's quite important that the rear edge of the board be supported only by the heatsink transistor leads.** Basically, this avoids the risk of eventually cracking the PC tracks and pads around the heatsink transistors due to thermal expansion and contraction of their leads as they heat up and cool down.

In short, the rear spacers are installed only while you install the heatsink transistors and must then be removed. They play no part in securing the module. Instead, this edge of the module is secured by bolting the heatsink itself to the chassis.

This can be done by tapping M3 or M4 holes into the main plate on the underside of the heatsink or by using right-angle brackets. The front of the board can be secured using the two M3 × 10mm spacers fitted earlier.

That completes the assembly of the power amplifier module. The next step is to build the power supply module.

Power supply module

As noted last month, this design dispenses with a regulated power supply. Instead, it is powered using unregulated +55V and –55V supply tails.

Fig.13 shows the circuit details of the power supply. It's based on a centre-tapped (toroidal) mains transformer (T1) with two 40V windings and two 15V windings.

As shown, the two 40V windings are connected together to give 80V AC centre-tapped, and this arrangement drives bridge rectifier BR1. This in turn feeds six 4700µF 63V electrolytic

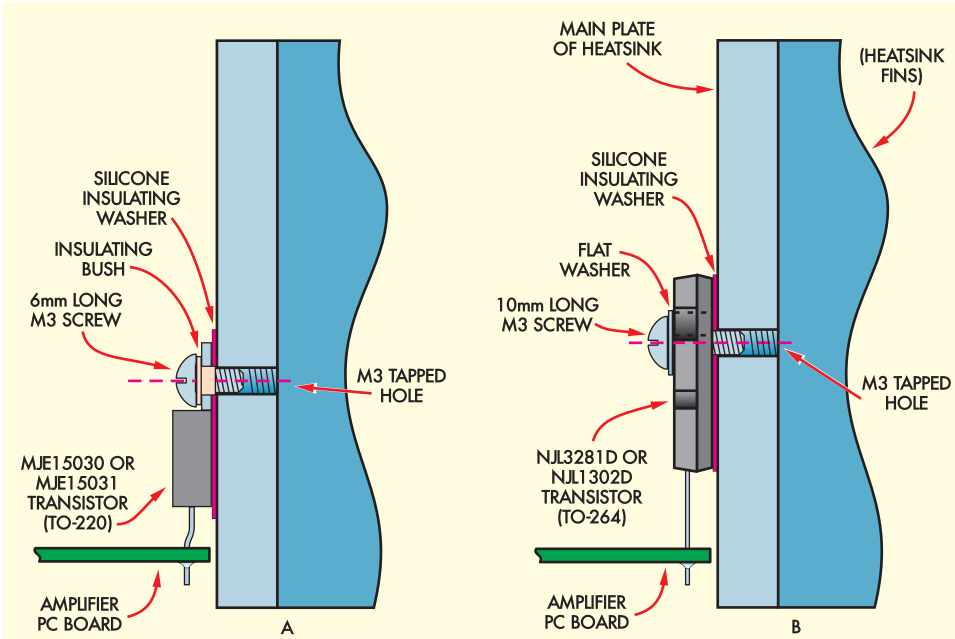


Fig.12: this diagram shows the mounting details for the TO-220 driver transistors (A) and the four output transistors (B). After mounting these transistors, use your multimeter to confirm that they are properly isolated from the heatsink – see text.

capacitors (ie, 14,100µF on each side) to provide balanced ±55V DC supply rails to power the amplifier.

In addition, two LEDs are connected in series with 3.3kΩ 5W current-limiting resistors across the ±55V supply rails. These serve two purposes: (1) they provide a handy indication that power is present on the supply rails; and (2) they (slowly) discharge the filter capacitors when the power is switched off (see warning panel).

The two 15V windings are also connected together (to provide 30V AC centre-tapped) and these drive bridge rectifier D1-D4 and two 2200µF filter capacitors to derive unregulated rails of about ±20V. These rails are then fed to 3-terminal regulators REG1 and REG2 to derive regulated ±15V supply rails to power a preamplifier module.

In addition, the +20V DC rail is also made available as an output, along with a 30V AC output. The +20V rail can be used to power the *Universal Speaker Protector and Muting Module* (*EPE*, Dec '08), while the 30V AC output is connected to the 'AC Sense' input of this module (it's used to quickly disconnect the speaker when the power goes off, to avoid switch-off thumps).

By the way, if you're looking for a preamplifier to use with the Ultra-LD Amplifier, the preamplifier module described in *EPE*, Dec '08 (and used in the *Class-A Stereo Amplifier*) is ideal.

Note, however, that 3-terminal regulators REG1 and REG2 on that preamplifier board must be replaced by wire links if powering it from the power supply described here. These links are connected between what were the IN and OUT pads for each regulator on the preamplifier board.

Power supply assembly

Fig.15 shows the parts layout for the Power Supply board. This board is coded 768 (PSU) and carries all the parts following the transformer except for 35A bridge rectifier BR1, which must be mounted on a metal chassis to ensure adequate heatsinking.

Begin by installing diodes D1-D4, the two LEDs and 3-terminal regulators REG1 and REG2. Make sure these parts are all orientated correctly and don't get REG1 and REG2 mixed up.

Both regulators are mounted with their metal tabs flat against the PC board. To install them, first bend their centre leads down through 90° about 5mm from their bodies, then bend their outer leads down through 90° about 7mm from the bodies. The regulators can then be fitted to the PC board and secured using M3 × 6mm screws, flat washers and nuts.

Tighten the screws firmly before soldering the device leads.

Note that there's enough room on the PC board to fit mini-heatsinks to the regulators. This will depend on

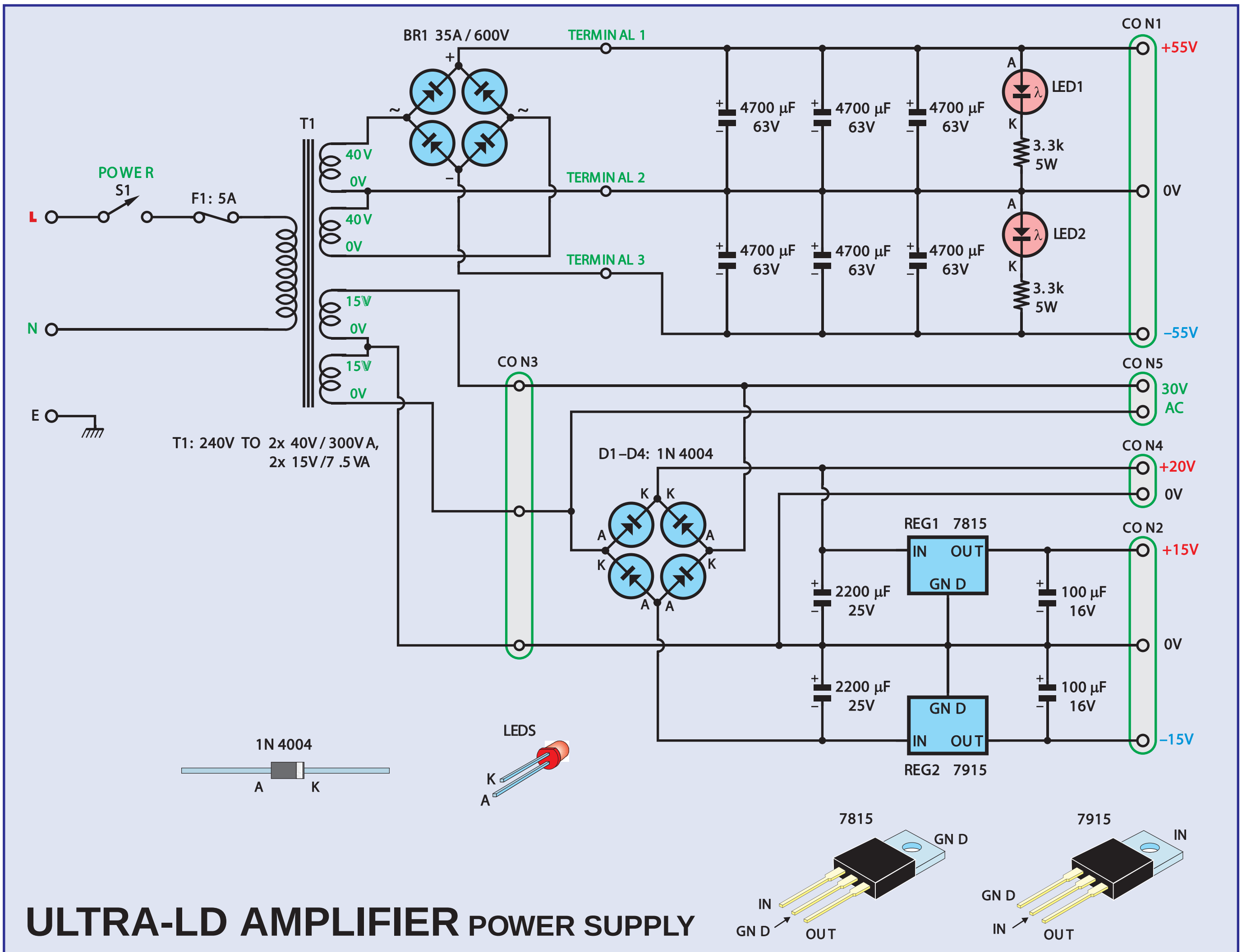


Fig.13: the power supply is based on a toroidal transformer (T1) with two 40V windings and two 15V windings. The two 40V windings are connected in series and drive bridge rectifier BR1 and six 4700µF filter capacitors to produce the ±55V rails. Similarly, the 15V windings drive a bridge rectifier based on diodes D1 to D4. This feeds 3-terminal regulators REG1 and REG2 to produce ±15V rails for a preamplifier. The +20V rail, derived from the output of D1 to D4, is used to power the loudspeaker protector.

the current drawn by the preamplifier you elect to use, but should not be necessary in most cases.

The three Quick-Connect male spade terminals (TERMINAL1 to TERMINAL3) are next on the list. These are used to terminate the connections from bridge rectifier BR1 and the centre-tap of the 40V transformer windings. They are each secured in place using an M4 × 10mm screw, nut, flat washer and star washer – see Fig.14.

The trick here is to use a Phillips-head screwdriver to hold the M4 screw stationary while you do up the nut with a ratchet-driven socket.

Once all the Quick-Connect terminals have been tightly secured to the PC board, you can then install the remaining parts. These include the two 3.3kΩ 5W resistors, the electrolytic capacitors and the screw terminal blocks. Note that the two 5W resistors should be stood off the board by 1-2mm, to allow the air to circulate beneath them for cooling (use a cardboard spacer).

Be sure to install the electrolytic capacitors with the correct orientation. These things have a nasty habit of exploding if they're installed the wrong way round – so double-check them.

Be sure also to dovetail connectors CON3 and CON5 together (to form a 5-way connector) before installing them on the PC board. If you solder one connector to the board first, you may not be able to dovetail them. The same goes for connectors CON4 and CON2.

Putting it in a case

The completed amplifier module and its power supply must be housed in an earthed metal case, but we'll leave the details of this up to you. **However, don't get involved in mains wiring unless you are experienced and know exactly what you are doing.**

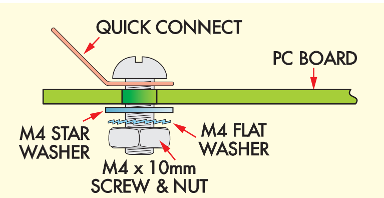


Fig.14: here's how the single-ended male Quick Connects are secured to the Power Supply module PC board.

Fig.16 shows the suggested wiring layout (but without a speaker protector or preamplifier). **Make sure that the chassis is securely earthed via**

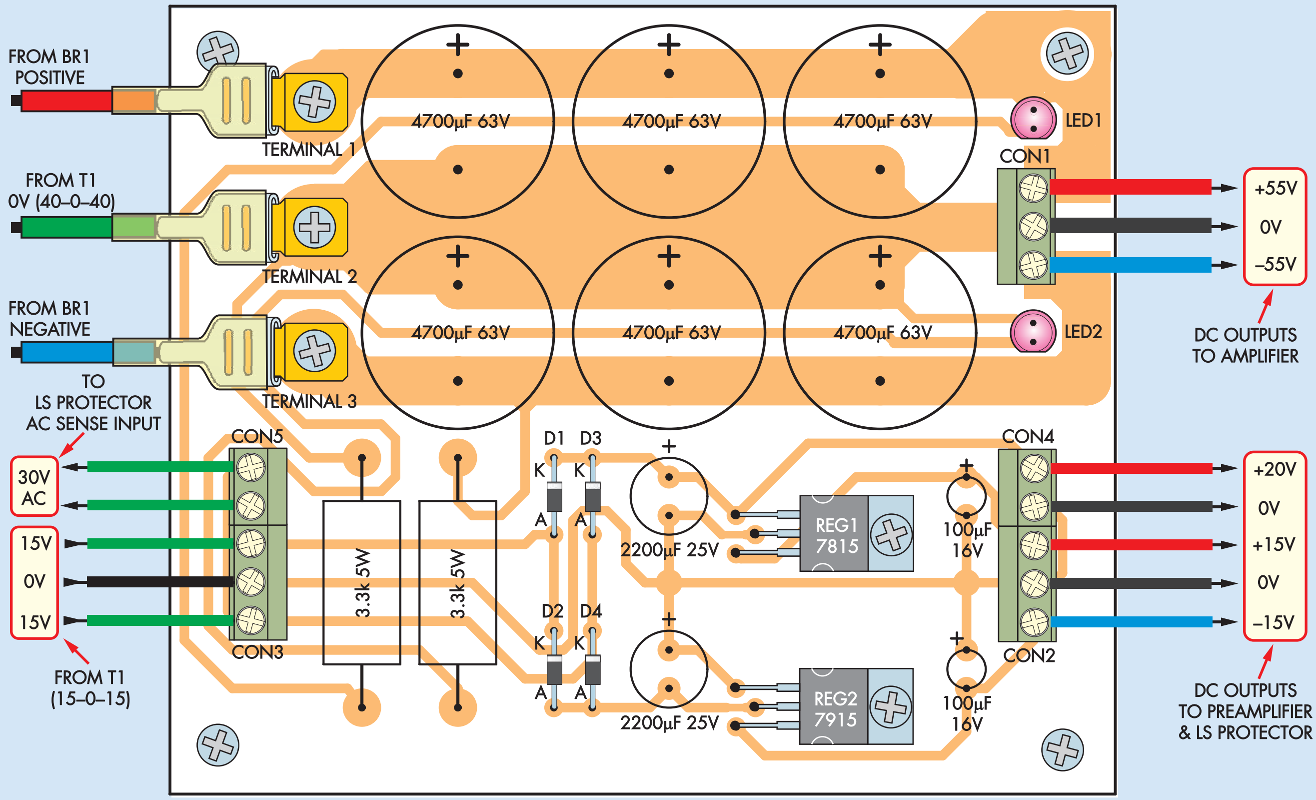
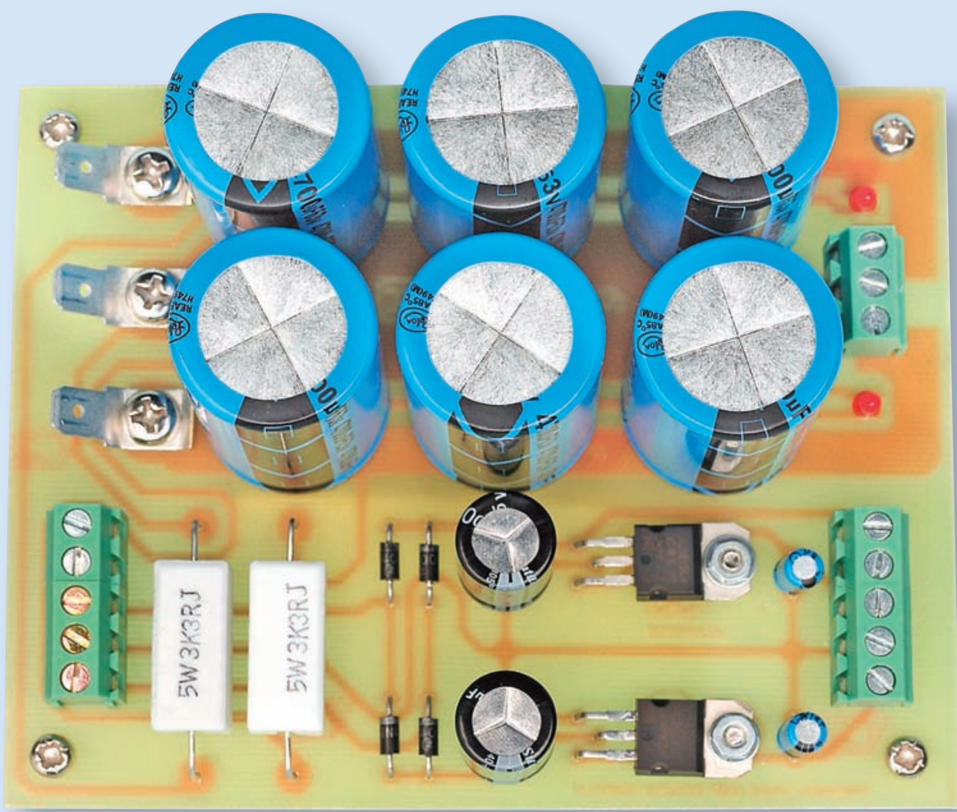


Fig.15: install the parts on the power supply board as shown here, taking care to ensure that all the electrolytic capacitors are mounted with the correct polarity. Be sure also to use the correct regulator at each location. The two LEDs indicate when power is applied and remain lit until the 4700µF capacitors discharge after switch-off.



We modified the power supply PC board after this prototype was produced, so that heatsinks could be fitted to the two 3-terminal regulators if necessary. This will depend on the current drawn by the preamplifier you elect to use.

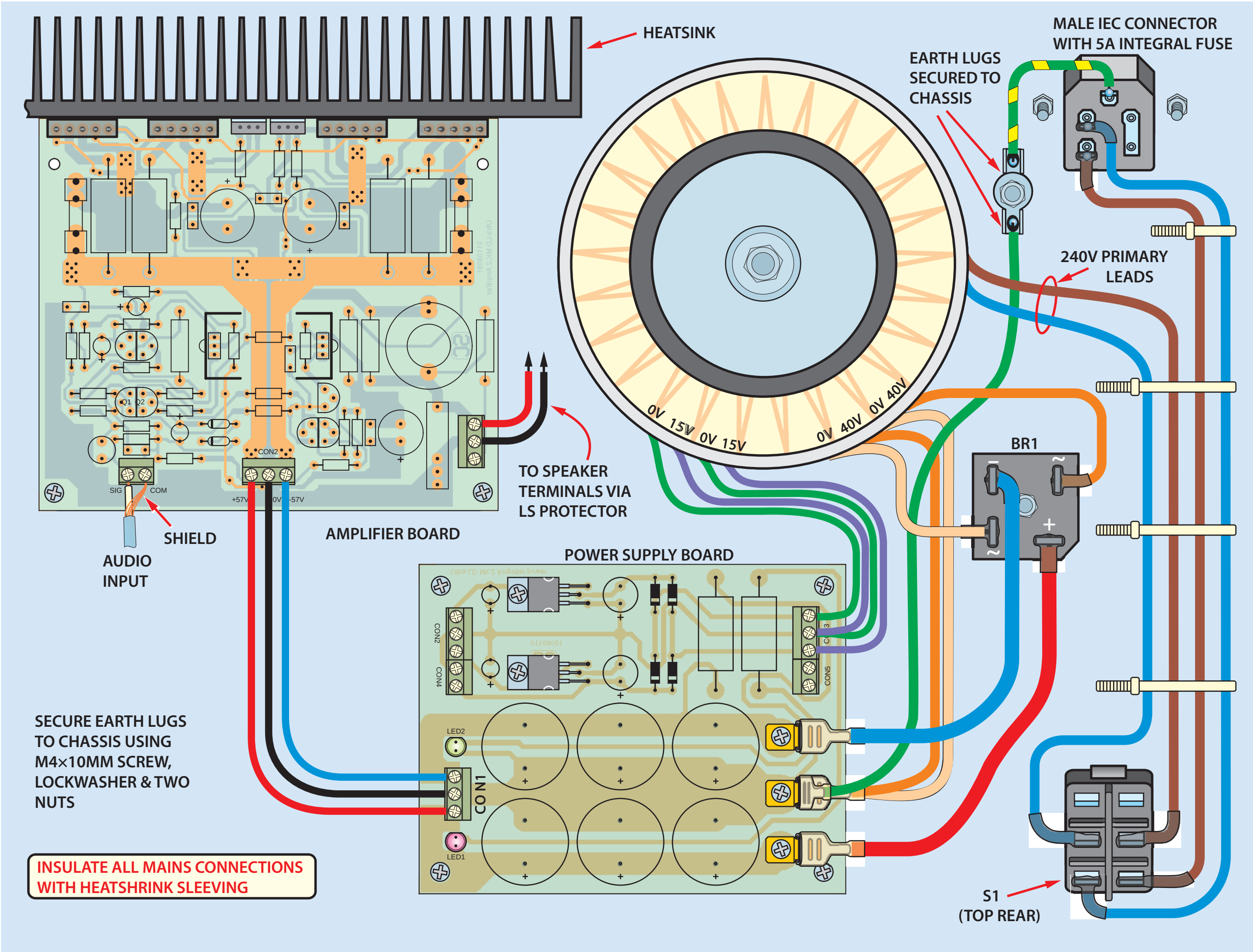


Fig.16: here's how to wire the completed power amplifier and power supply boards into a metal case. The mains wiring at right would be typical of most installations, but ensure that all exposed terminals are fully insulated.

the mains and be sure to insulate all exposed mains terminals.

Note that you will have to use a piggyback female spade connector to terminate the commoned 40V and 0V connections from the toroidal transformer. This connector plugs into the 0V terminal (TERMINAL 2) on the power supply module. The female spade connector fitted to the green earth lead is then plugged into the back of this connector.

The other end of this earth lead is crimped to an earth lug. Similarly, the mains earth lead (green/yellow) is crimped to a second earth lug and the two earth lugs are securely bolted to the chassis.

Once the assembly is complete, check your wiring very carefully. In particular, make sure that BR1's positive and negative terminals connect to the correct terminals on the power supply board.

You should also use a multimeter to confirm that the chassis is correctly earthed. Do that by checking for continuity between the earth terminal of the IEC socket and the chassis.

Testing the power supply

It's now time to check that the power supply is functioning correctly, but first a warning: **You must avoid contact with the ±55V rails, both on the power supply module and on the amplifier module. There's 110V between them and getting across the two rails simultaneously could have serious consequences.**

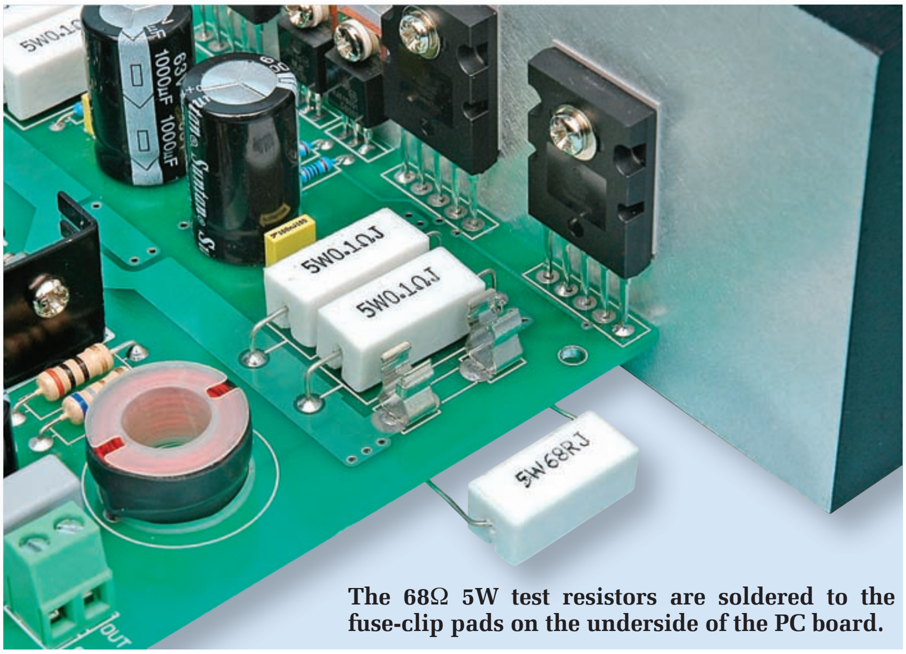
The same goes for the transformer secondary windings – make sure that you don't 'bridge' across either of the two 40V AC windings or the 80V AC that's applied to bridge rectifier BR1.

You must also allow the 4700μF filter capacitors on the power supply module to discharge down to a couple of volts before attempting to work on this module. Don't just rely on the LED indicators – use your multimeter to confirm that the supply rails have indeed dropped to a low value before touching them.

Similarly, make sure these capacitors have discharged before connecting the power supply to the amplifier module or disconnecting it (otherwise you could damage the amplifier).

To check the power supply, first make sure that the supply wiring is disconnected from the amplifier. That done, apply power to the power supply board and check the various DC outputs. You should be able to measure close to ±55V on CON1, +20V on CON4, ±15V on CON2 and 30V AC on CON5.

If you don't get the correct voltages, switch off immediately and check for wiring and component errors.



The 68Ω 5W test resistors are soldered to the fuse-clip pads on the underside of the PC board.

Testing the power amplifier

Assuming you do get the correct voltages, switch the power supply off and follow this step-by-step procedure to check the power amplifier module:

STEP 1: remove the fuses from the amplifier module and install two 68Ω 5W resistors in their place. The best way to do this is to tack solder the resistors across the fuseholder pads on the underside of the PC board. They should be mounted about 5mm away from the edge of the board, to prevent heat damage during testing – see photo.

The 68Ω resistors are there to limit the current through the output stage to about 800mA if there is a fault in the amplifier that turns the output transistors hard on. This protects the output transistors from damage, but note that the 68Ω resistors will quickly burn out under such circumstances (since they will be dissipating over 40W).

STEP 2: use your multimeter to again check that the heatsink transistors are all isolated from the heatsink. If one of these is shorted, its corresponding 68Ω 5W resistor will again quickly burn out if power is applied.

STEP 3: check that the power supply is off and that the filter capacitors are discharged, then connect the +55V, 0V and –55V supply leads to the amplifier at CON2. Make sure these are connected correctly, otherwise the amplifier will be damaged when power is applied.

STEP 4: apply power and check the supply voltages at the fuseholders (ie, at the ends furthest away from the heatsink). You should get +55V at FUSE1 (with respect to the 0V rail) and –55V at CON2.

STEP 5: check the voltage across each 68Ω 5W resistor. This should be in the range from 9V to 14V (depending on the supply rails and the exact value of the 68Ω test resistors).

Switch off immediately and go to the troubleshooting procedure if you get a value that's much higher than 14V.

STEP 6: check the voltage at the loudspeaker terminals. You should get a reading of ±30mV or less.

STEP 7: check the voltage across each of the 0.1Ω 5W emitter resistors in the output stage. **This voltage should be between 7mV to 10mV.** This equates to a current of 70-100mA through each output transistor, which means that the total output stage quiescent current is in the range of 140mA to 200mA.

Be careful not to short a resistor lead to the adjacent +55V and –55V tracks on the top of the board when making these voltage checks.

If the voltage across the 0.1Ω 5W emitter resistors exceeds 10mV, increase the 47Ω resistor between the supply rail and Q7's emitter to 56Ω, or even to 68Ω if necessary to bring the voltage back into the 7mV to10mV range. This resistor is located on the far lefthand side of the PC board, immediately below a 100nF capacitor.

Do not reduce Q7's emitter resistor to less than 47Ω.

Parts List – Power Supply

PC Board Module
1 PC board, code 768 (PSU), available from the *EPE PCB Service*, size 126mm × 96mm
3 3-way PC-mount terminal blocks, 5mm pitch (CON1-CON3)
2 2-way PC-mount terminal blocks, 5mm pitch (CON4-CON5)
3 chassis-mount single-ended Quick Connect (spade) terminals (TERM1-TERM3) (Jaycar PT-4910 or equivalent)
3 M4 × 10 screws
3 M4 a 10mm nuts
3 M4 flat washers
3 M4 shakeproof washers
4 M3 × 9mm tapped nylon spacers
6 M3 × 6mm screws
6 M3 nuts
2 M3 shakeproof washers

Semiconductors
4 1N4004 diodes (D1-D4)
1 7815 15V regulator (REG1)
1 7915 –15V regulator (REG2)
2 3mm red LEDs (LED1,LED2)

Capacitors
6 4700µF 63V radial electrolytic
2 2200µF 25V radial electrolytic
2 100µF 16V radial electrolytic

Resistors
2 3.3kΩ 5W

Additional Parts
1 300VA transformer with 2 × 40V AC 300VA windings and 2 × 15V AC 7.5VA windings
1 35A 400V bridge rectifier (BR1)
1 chassis-mount IEC male socket with fuseholder (eg, Jaycar PP-4004)
1 DPST mains switch (S1)
1 M205 5A fuse

Miscellaneous
Earth crimp lugs, female Quick Connectors, 240V AC cable, machine screws and nuts

Removing parts from the PC board

If you need to remove components such as resistors or transistors from this double-sided board, the easiest way to do it is to first remove as much solder as you can from each pad using a solder sucker. Next, you clip away the body of the component using small side-cutters, then grab each lead with needle-nose pliers on the top of the board while you heat up its copper pad underneath. The lead can then be pulled out from the top.

You then use solder-wick (or desoldering braid) to remove any residual solder. Be careful not to overheat the PC pads, as they may detach themselves from the board. Often, it will be necessary to drill out the holes to clear the solder, so that you can install the new component's leads.

STEP 8: check the voltages marked on the circuit diagram (Fig.1) last month. These should all be close to the indicated values.

STEP 9: if everything is correct, switch off and allow the power supply filter capacitors to discharge to a low level (2V or less). When they reach this level, disconnect the power supply, remove the 68Ω 5W resistors from the amplifier module and install the 5A fuses.

STEP 10: connect an audio signal source and a loudspeaker (preferably via a loudspeaker protector module), then re-apply power and test the amplifier module with music.

Troubleshooting

If the voltage across the 68Ω test resistors is much greater than 14V (eg, close to the supply rail), switch off immediately (note: the resistors may burn out before you do this).

The first thing to check is that the heatsink transistors are all correctly isolated from the heatsink. If this checks out, apply power to the amplifier without the fuses or test resistors in place – ie, so that the output stage (Q10 to Q15) is left unpowered.

Now check the voltage between the bases of transistors Q10 and Q11. This should be close to 2.2V. If it's much higher than 2.2V, this indicates that the DQ12 to DQ15 diode string is open circuit. This could be due to an open-circuit track on the PC board or more likely, a missed solder connection on one of the output transistor leads (ie, the 'A' and 'K' diode leads).

If the voltage across the diode string is correct, check the base-emitter voltage of each transistor in the amplifier.

In each case, you should get a reading of 0.6V to 0.7V if the transistor is working correctly. Check that the correct transistor has been used at each location.

Loudspeaker protection

Finally, be sure to use this module with a loudspeaker protector, as a fault in the output stage can quickly burn out an expensive loudspeaker system (and maybe even start a fire due to a red-hot voice-coil). The recommended unit is the *Universal Speaker Protector and Muting Module* (see *EPE*, Dec '08). ***EPE***

PLEASE TAKE NOTE

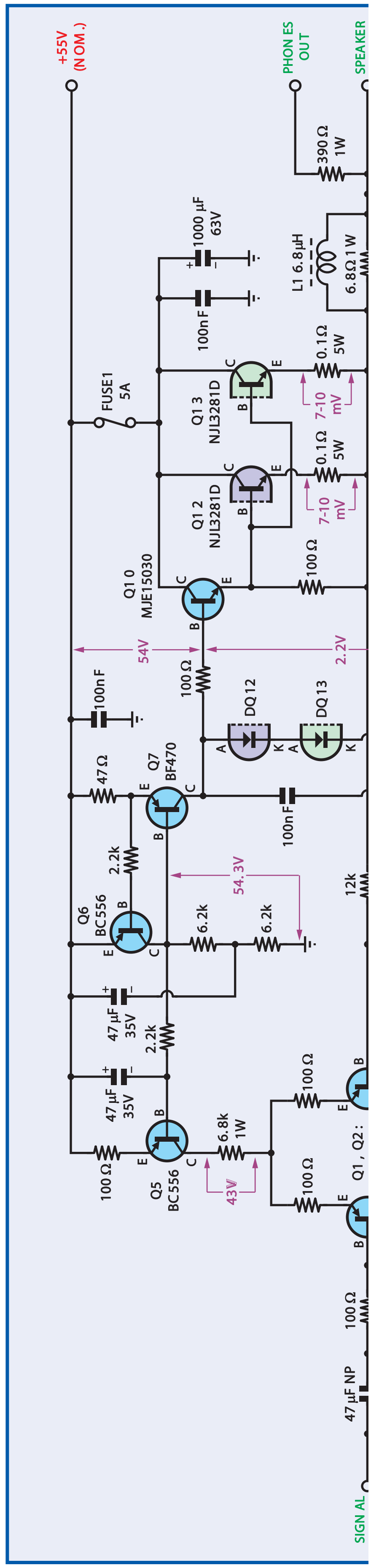
Ultra-LD 200W Power Amplifier – Pt.1 *(Aug '10)*

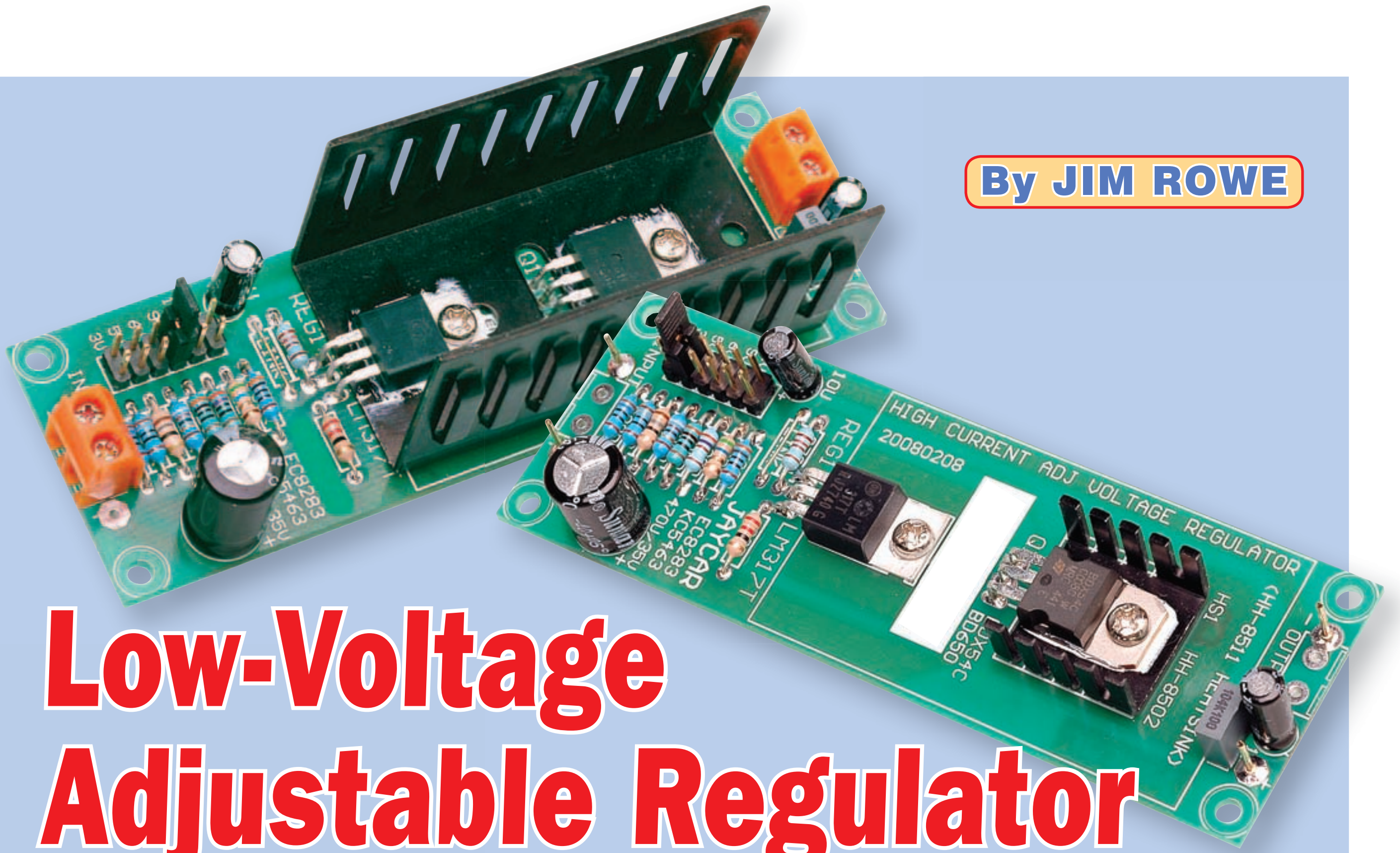
Page 36, Fig.1. Unfortunately, the register of the circuit diagram shifted during the final processing of the page for printing and the top, power supply line, of the circuit is missing. We have reproduced the top section, including the positive supply line, opposite. We apologise for this error.

EPE PCB Service *(Aug '10)*

Page 70. There is a misprint in the Aug '10 section. The entry for the *Ultra-LD 200W Power Amplifier PCB* showed the wrong price.

This board is a double-sided PCB. The correct price is given in this month's *PCB Service* entry.





By JIM ROWE

Low-Voltage Adjustable Regulator

Need to operate a CD, DVD or MP3 player from the cigarette lighter socket in your car? Or perhaps run a digital still or video camera or some powered speakers from the power supply inside your PC? This Low-Voltage Adjustable Regulator will step the voltage down to what's needed. It has jumper shunts to select one of six common output voltages (from 3V to 15V) and depending on the input voltage and the heatsink(s) you use, it can deliver an output current of just over 4A.

CONSIDERING the price of batteries and the ever-growing array of small items of electronic gear designed to run from low-voltage battery power, it's not surprising that one of the most common requests from readers is for an adaptor so this kind of equipment can be run from either the power supply inside a PC or a cigarette lighter socket in a motor vehicle.

Most of the battery-operated equipment we're talking about is designed to operate at 3V, 6V or 9V, whereas the voltages available from vehicle batteries or PC power supplies are rather more restricted. For example, there's usually only either 12V or 24V available from vehicle batteries, while most PC power supplies only have 5V and 12V supplies readily available.

In addition, the voltage available from a vehicle battery can vary over a fairly wide range, depending on whether the engine is running, the battery is being charged and whether the lights and/or air conditioning are on. This sort of voltage variation can cause problems for electronic circuits, as these generally perform much better and more reliably when operated from a regulated power supply.

This Low-Voltage Adjustable Regulator has been designed for use in virtually any of these common DC voltage step-down applications. It can be connected to any convenient source of input voltage up to about 28V and is 'programmed' using a push-on jumper shunt to deliver one of six output voltages: 3V, 5V, 6V, 9V, 12V or 15V. In each case, the output voltage is well regulated, remaining very close to the selected voltage despite broad changes in both input voltage and load current level.

Circuit description

The full circuit is shown in Fig.1. The heart of the adaptor is an LM317T adjustable 3-terminal regulator, which comes in a TO-220 package.

The LM317 is designed to maintain the voltage between its output (OUT) and adjustment (ADJ) terminals at close to 1.25V. At the same time, the current level through its ADJ terminal is maintained at a very low level (typically 50μA) and varies by less than 5μA over the full rated load current range (10mA – 1.5A) and the input-output voltage range of 3V to 40V.

The LM317's actual regulated output voltage can be varied over a wide range using a simple resistive voltage divider. As shown in Fig.1, the divider's top resistor is connected between the OUT and ADJ terminals of REG1, while the bottom resistor is connected between the ADJ terminal and the negative voltage rail.

Since the LM317 maintains the voltage across the upper resistor at 1.25V, the total output voltage can be set for virtually any voltage above this level simply by adjusting the value of the lower divider resistor. The value of the lower resistor is found by taking into account that it needs to drop the desired output voltage minus 1.25V, while carrying the current passing through the upper resistor, plus an additional 50μA (from the ADJ terminal).

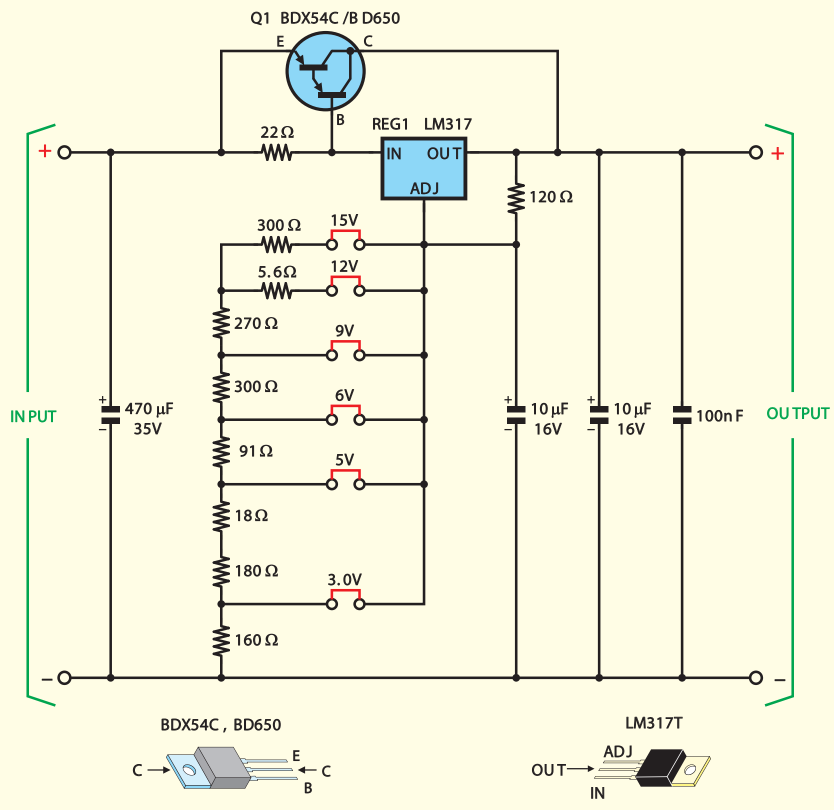
In our circuit, the upper divider resistor is 120Ω, giving a nominal current of 1.25/120 = 10.42mA. Hence the current through the lower divider resistor is 10.42 + 0.05 = 10.47mA.

The value of the lower divider resistance is varied using the jumper shunt to link one of the six 'voltage select' pin pairs. For example, when the shunt is fitted in the 3V position, the lower divider resistor is 160Ω. Similarly, when it's fitted in the 6V position the lower resistor value is set to (160 + 180 + 18 + 91) = 449Ω.

The resistor values selected by each of the jumper shunt positions have been calculated to give LM317 output voltages as close as possible to the marked values, using standard resistor tolerance values.

Specifications

- **Selectable output voltage:** 3V, 5V, 6V, 9V, 12V or 15V DC within ±3%
- **Output voltage regulation:** typically better than 0.5% up to 500mA; better than 1% for output currents up to 1A
- **DC Input voltage:** up to 24V battery
- **Output current:** up to 4.25A – see Table 1.



HIGH CURRENT ADJUSTABLE REGULATOR

Fig.1: the circuit is based on an LM317 adustable regulator and a *PNP* Darlington transistor (Q1) to boost the output current capability. The output voltage is set by the resistive voltage divider string on the regulator's OUT and ADJ terminals and depends on the jumper shunt installed.

Current boost

So that is how we set the output voltage. However, since the LM317 can only cope comfortably with currents up to around 1.5A, it needs a boost if the adaptor is to supply higher currents. In our circuit, this boost is provided by Q1, a BDX54C/BD650 *PNP* Darlington power transistor.

Q1 has its emitter and base connected across the 22Ω resistor in series with the LM317's input. As a result, the voltage developed across the 22Ω resistor when the LM317 draws current provides Q1 with forward bias.

When the current drawn by the load through the LM317 rises to about 55mA, the voltage drop across the 22Ω resistor will be around 1.2V. This is enough to forward bias Q1 into conduction. As the load current rises above this 55mA level, Q1 gradually takes over from the LM317 and handles more and more of the load current. The higher the load current, the greater the proportion that's handled by Q1.

The current boost provided by Q1 doesn't degrade the voltage regulation performance of the LM317. The regulator still controls the output voltage level closely in the normal way and varies the current passing through Q1 by varying its own current. In effect, Q1 acts purely as a slave to REG1, boosting the total output current capacity.

The function of the 470μF capacitor across the adaptor's input is to provide a degree of smoothing and filtering, to minimise the effect of any alternator noise or power supply ripple that may be present on the input voltage. Further filtering is provided by the 10μF capacitor, which is connected between the LM317's ADJ terminal and the negative voltage rail, and also by the 100nF and 10μF capacitors across the output.

Table 1: Voltage Adaptor Output Current Ratings

Input Volts	Output Volts	Vin – Vout	Maximum output current: With HH-8502 heatsink (on board)	With HH-8511 heatsink (on board)	With Q1 on HH-8566 heatsink, off board
6V	3V	3V	830mA	2A	2.8A
12V	3V	9V	275mA	660mA	940mA
	5V	7V	350mA	850mA	1.2A
	6V	6V	415mA	1A	1.4A
	9V	3V	830mA	2A	2.8A
24V	3V	21V	115mA	280mA	400mA
	5V	19V	130mA	310mA	440mA
	6V	18V	135mA	330mA	470mA
	9V	15V	160mA	400mA	560mA
	12V	12V	200mA	500mA	700mA
	15V	9V	275mA	660mA	940mA

Table 1: use this table to select the heatsink necessary to suit the required output current from the regulator board. Note that you also have to consider the difference between the input and output voltages when making this selection.

Current, power and heatsinking

Before we turn to the construction of the adaptor, it's important to understand how the amount of load current is determined by two factors:

1) The difference between the input voltage and selected output voltage.

2) The amount of heatsinking fitted to current booster Q1 (and to a lesser extent, regulator REG1).

These things are all linked together because the main limitation on the adaptor's maximum output current is the heat dissipation in both Q1 and REG1. Q1 can only dissipate a little over 20W for case temperatures up to 100°C, while REG1 has internal over-current and over-temperature protection, which limits its power dissipation to less than about 15W.

These limits control the adaptor's output current because the case temperatures of Q1 and REG1 are proportional to the power they have to dissipate, and their power dissipation is determined in turn by the voltage they have to drop (ie, the difference between the adaptor's output and input voltages) multiplied by the output current.

We can express this mathematically using the following equation:

$$P(tot) = I(load) \times (V_{in} - V_{out})$$

where P(tot) is the total power dissipation in watts, I(load) is the load current in amps and V_{in} and V_{out} are the adaptor input and output voltages respectively.

So, the important point to grasp is that the larger the voltage difference ($V_{in} - V_{out}$), the smaller the maximum load current that the adaptor can handle.

Just how hot Q1 and REG1 actually get for a given amount of power dissipation depends on the heatsink size. To be precise, the temperature rise for each device is determined by the power being dissipated and the 'thermal resistance' between its internal junction and the surrounding 'ambient', as follows:

$$T(case - ambient) = P(tot) \times R(j\text{-}a)$$

where T(case – ambient) is the case temperature rise above ambient and R(j-a) is the thermal resistance between the junction and ambient. The latter is made up from two thermal resistances in series; the junction to case thermal resistance and the thermal resistance from case to ambient:

$$R(j\text{-}a) = R(j\text{-}c) + R(c\text{-}a)$$

where R(j-c) is the internal thermal resistance from junction to case, which is around 4°C per watt for TO-220 devices like Q1 or REG1. R(c-a) is the thermal resistance from case to ambient, which we can lower by fitting the device with a heatsink.

For example, the thermal resistance R(c-a) of a TO-220 device like Q1 without any heatsink at all is around 46°C/watt, so its temperature will rise above ambient by about (4 + 46) = 50°C for every watt of power it must dissipate.

If we fit it with even a small heatsink, like the Jaycar HH-8502, this drops R(c-a) to 20°C/watt, lowering the total temperature rise above ambient to (4 + 20) = 24°C for each watt of power dissipated. So, fitting this small heatsink on Q1 will roughly double the adaptor's power dissipation ability.

We can do much better if we fit Q1 with a larger heatsink, like the Jaycar HH-8511 (which can be shared with REG1 as the latter doesn't dissipate much power). The larger heatsink reduces R(c-a) to 6°C/watt, resulting in a total temperature rise of only (4 + 6) = 10°C for each watt dissipated.

It is possible to reduce the value of R(c-a) even further by fitting Q1 with an even larger heatsink, to allow it to

Table 2: Resistor Colour Codes

❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	2	300Ω	orange black brown brown	orange black black black brown
❏	1	270Ω	red violet brown brown	red violet black black brown
❏	1	180Ω	brown grey brown brown	brown grey black black brown
❏	1	160Ω	brown blue brown brown	brown blue black black brown
❏	1	120Ω	brown red brown brown	brown red black black brown
❏	1	91Ω	white brown black brown	white brown black gold brown
❏	1	22Ω	red red black brown	red red black gold brown
❏	1	18Ω	brown grey black brown	brown grey black gold brown
❏	1	5.6Ω	green blue gold brown	green blue black silver brown

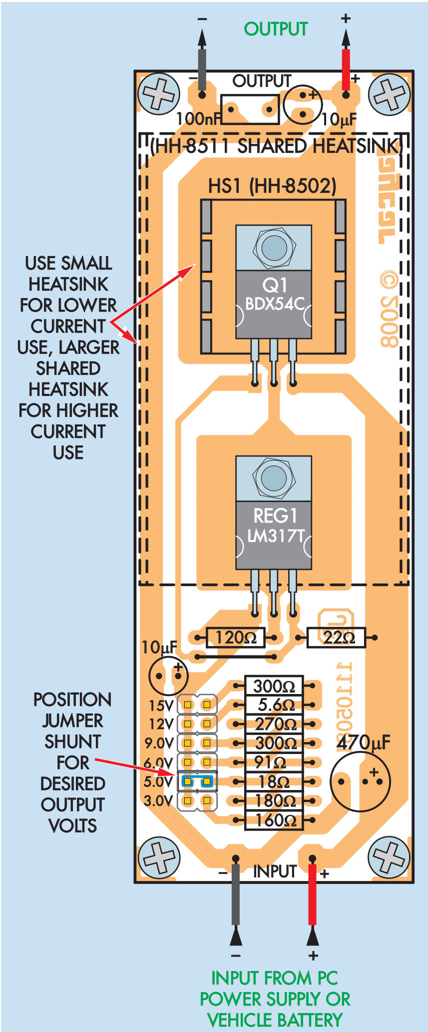


Fig.2: install the parts on the PC board as shown here. The output voltage is set by installing a jumper shunt in one of the link positions.

dissipate even more power. However this involves mounting Q1 off the adaptor's PC board.

To summarise, if you want the adaptor to supply as much current as possible, you must limit (V_{in} – V_{out}) by reducing V_{in}. **However, V_{in} must be at least 3V higher than V_{out} for the adaptor to work correctly.**

If you're stuck with a particular input voltage (say 12V), the only way to increase the adaptor's output current capability is to provide Q1 with a larger heatsink, as just discussed.

Example

Let's say you want to use the adaptor to power a portable CD player from the cigarette lighter socket in your car and the CD player needs 3V DC. So V_{in} is 12V and the adaptor will have to drop 12 – 3 = 9V.

Now let's assume that Q1 is fitted with just a small HH-8502 heatsink. What current will it be able to deliver to the CD player at ambient temperatures up to 40°C?

From what we've seen earlier, the total R(j-a) for Q1 with this small heatsink is around 24°C/watt, so if we want its temperature to rise by no more than 60°C above an ambient of 40°C (ie, to 100°C maximum), the maximum power that Q1 should be called upon to dissipate is 60/24 = 2.5W. If the adaptor will be dropping 9V, this corresponds to a maximum load current of 2.5/9, or about 275mA (power = voltage × current, so current = power/voltage).

If the CD player needs to draw more current than this, you'll have to fit Q1 with a larger heatsink like the HH-8511 which allow it to deliver 6/9A, or about 660mA.

If this current rating seems pretty low, consider that this example is for a very demanding situation where it is being called upon to deliver the lowest selectable output voltage but from a fairly high input voltage.

For an easier example, let's say you want to provide a radio or some other equipment with 9V, but still want to run the adaptor from 12V. This will mean that Q1 will only have to drop (12 – 9 = 3V). So, with the smaller HH-8502 heatsink it would be able to deliver up to 2.5/3 or 830mA. Alternatively, with the larger HH-8511 heatsink, it would be able to supply 6/3 or 2A.

To make it easier to choose which size of heatsink you need for your application, refer to Table 1 for the most likely combinations of input voltage and output voltage. Note that only practical combinations are shown – ie, where the input is at least 3V higher than the output, so that the unit can operate correctly.

Construction

All the parts used in the adaptor mount on a small PC board measuring 107 × 39mm. This board is available from the *EPE PCB Service* code 769.

The component overlay diagram is shown in Fig.2. Begin assembly by fitting the four PC board terminal pins (to the external wiring points) and the 6×2 length of DIL jumper strip used for the output voltage programming. Follow these with the single wire link that goes just below the 120Ω resistor.

Next, fit the 10 resistors to the board, taking care to place each one in its correct position. Table 2 shows the resistor colour codes, but you should also check each resistor using a DMM before soldering it in, as some of the colours can be difficult to decipher.

After the resistors, you can install the capacitors, starting with the unpolarised 100nF MKT capacitor up at the top/output end. Follow this with the three electrolytic capacitors, taking care to fit each of these the correct way around because they are polarised.

The next step is to fit the heatsink (either the HH-8502 or the larger

Parts List

- 1 PC board, code 769, available from the *EPE PCB Service*, size 107 × 39mm
- 1 HH-8502 19mm square TO-220 heatsink, OR
- 1 HH-8511 61 × 36 × 30mm U-shaped heatsink
- 2 TO-220 silicone washers
- 1 6x2 length of DIL jumper strip
- 1 jumper shunt
- 2 M3 × 6mm machine screws
- 2 M3 nuts
- 4 PC board terminal pins, 1mm diameter

Semiconductors

- 1 LM317T regulator (REG1)
- 1 BDX54C or BD650 *PNP* power Darlington (Q1)

Capacitors

- 1 470µF 35V radial electrolytic
- 2 10µF 16V radial electrolytic
- 1 100nF MKT metallised polyester

Resistors (0.25W, 1% metal film)

2 300Ω	1 91Ω
1 270Ω	1 22Ω
1 180Ω	1 18Ω
1 160Ω	1 5.6Ω
1 120Ω	

Where to buy a kit

This project was developed by Jaycar Electronics and they own the copyright on the PC board. Kits will be available exclusively from Jaycar retail outlets and dealers (Cat. KC-5463) and will be supplied with the HH-8502 heatsink.

HH-8511 – see Table 1), along with REG1 and Q1. Each of the latter two devices is mounted 'flat' with its leads bent down by 90° about 6mm from its case, so they pass through the relevant holes in the PC board.

If you're just using the small HH-8502 heatsink for Q1, REG1 can be fitted directly to the board (ie, no heatsink) and its metal tab secured using an M3 × 6mm machine screw and nut. The machine screw and nut also provide REG1 with a small amount of incidental heatsinking, in conjunction with the copper square underneath.

Once you've secured its tab, its leads can be soldered to the copper pads under the board. Don't solder the leads before bolting down the tab – you could stress and crack the solder joints if you do.

Q1 is mounted on the top of its heatsink, using a thermal conducting washer or a smear of thermal compound to ensure a good thermal bond. An M3 × 6mm screw and nut are then used to secure the assembly in place, before soldering Q1's leads to their pads underneath.

Alternatively, both Q1 and REG1 can be mounted on the larger HH-8511 U-shaped heatsink, again using either thermal conducting washers or smears of thermal compound to ensure good thermal bonds. As before, bolt the assembly to the PC board before soldering the device leads.

Voltage on the heatsink

It is not really necessary to electrically isolate the metal tabs of Q1 and REG1 from each other (or from the heatsink), since they both sit at the output voltage (ie, Q1's tab is its collector and REG1's tab is its output terminal). **It does mean, however, that the heatsink also operates at the output voltage when power is applied, so make sure it doesn't short against other equipment.**

This is also an important consideration if you mount Q1 off the board on a large external heatsink. In that case, you might want to electrically isolate Q1 from the heatsink using a TO-220 insulation kit (ie, thermal insulation washer plus insulating bush for the mounting screw). That way, the heatsink can then be earthed to other equipment.

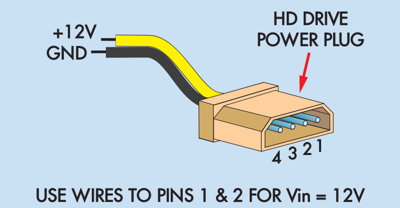


Fig.3: a hard disk drive power connector (eg, Jaycar PP-0743) can be used to connect the input of the regulator board to the 12V output from a PC power supply.

Voltage selection

The next step is to fit the voltage selection jumper shunt to select the required output voltage. That done, connect a DC power source (it *must* provide at least 3V more than the output voltage you want), then check the output voltage with your digital multimeter. It should be within ±3%.

If you are going to be sourcing the adaptor input voltage from your car or truck battery, the input lead can be fitted with a cigarette lighter plug at the far end to mate with the vehicle's cigarette lighter socket.

Similarly, if you intend sourcing the adaptor's input voltage from a PC power supply, the input lead can be fitted with a 4-way plug (as used on the rear of hard disk drives), to mate with a spare power connector inside the PC. Again, Jaycar can provide two versions of these plugs: the PP-0743 or the PP-0744.

Fig.3 shows the connections for using this type of plug to provide a 12V supply for the regulator board. Note, however, that this input voltage will only be suitable for output voltages up to 9V.

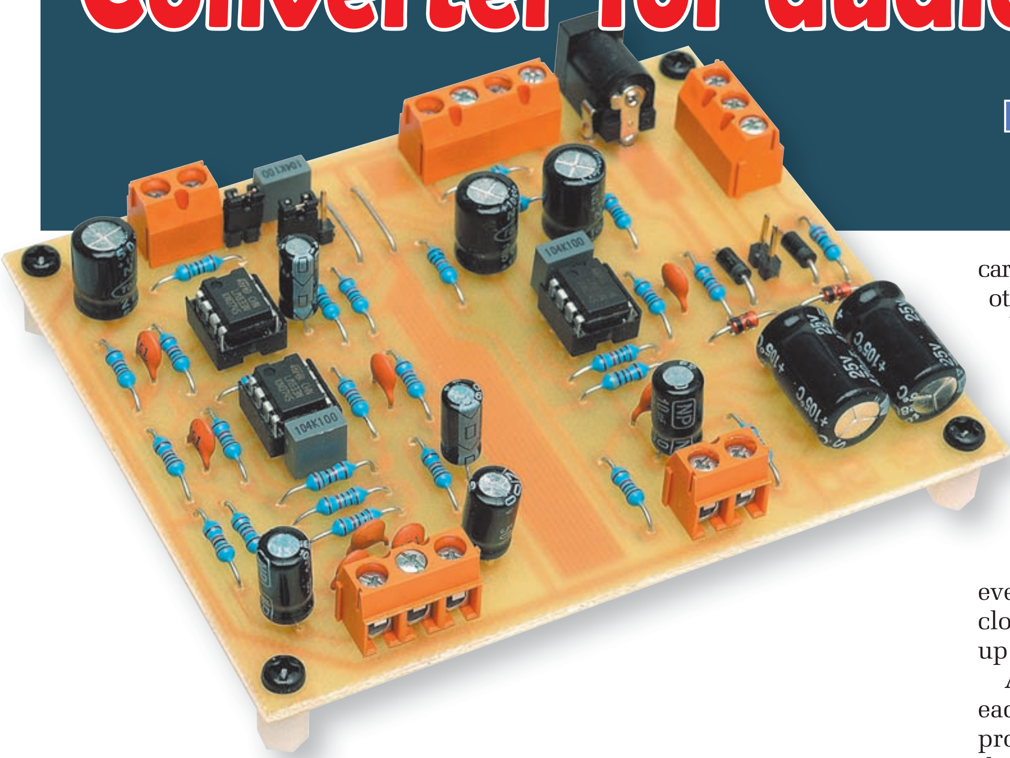
Output connector

The adaptor's output lead can be fitted with a power connector to suit the device or devices you're going to be powering. In many cases, this is likely to be a concentric low-voltage DC connector.

Finally, when mounting the adaptor inside a case, make sure it has adequate ventilation to dissipate the likely heat it will produce. ***EPE***

Balanced/Unbalanced Converter for audio work

By JOHN CLARKE



If you work in the professional audio field, you need to use balanced lines for long signal runs to prevent hum and noise pick-up. This Balanced/Unbalanced Converter is really two projects in one. It can convert an unbalanced input to balanced outputs and vice versa.

PROFESSIONAL audio gear invariably has balanced inputs and outputs. However, what if you want to connect standard audio equipment that has unbalanced outputs to equipment that has balanced inputs? Alternatively, what if you want to connect a balanced output signal to an unbalanced input? Either way, this Balanced/Unbalanced Converter project can do the job.

The reason professional audio equipment utilises balanced inputs and outputs is quite simple. It's done so that audio connections can be made over quite long distances without adding extra noise to the signal. These balanced connections use 3-pin XLR plugs and sockets and screened twin-core cable.

Basic arrangement

The basic arrangement for converting an unbalanced input signal to a balanced signal and back again is shown in Fig.1. Basically, the audio output signal is coupled to two separate amplifiers and these drive the two signal leads in the cable in anti-phase (ie, the signals have opposite phases). In this case, Amplifier 1 has an output signal that's in phase with the input, while Amplifier 2 has an output that's opposite in phase with the input.

The output impedance of each amplifier is the same and the twin-core cable carries the signal to the equipment at the other end. However, in some cheaper balanced line drivers, one core does not carry any signal but is grounded instead. So in this case, Amplifier 2 is left out and the lefthand side of resistor R2 is grounded.

In operation, there will be some noise and hum pickup over the length of the cable even though the cable is shielded. However, because the cores in the cable are close together, any signal that is picked up will be common to both.

At the receiving end, the signal in each of the two cores is subtracted to produce the original audio signal. At the same time, this also removes most of the noise and hum that was picked up in the leads, since the same noise signal is present in both.

If one of the cores is grounded, as in the cheaper type of balanced driver, then the signal level after subtraction will be the same as the signal in the main core. Alternatively, if anti-phase signals are applied to both cores, the subtraction process produces an audio signal level that's twice the level in the individual cores.

As well as increased signal level at the receiving end, using two anti-phase signals gives a better result than using a balanced line driver with an earthed line. There are several reasons for this.

First, when using two anti-phase signals, the two amplifiers that drive them are similar and basically follow the same impedance variations over the audio frequency range. Second, with the full anti-phase (or differential) lines, the electromagnetic field due to the signal in each is theoretically zero and so crosstalk into adjacent cables is minimised. And third, the cable will

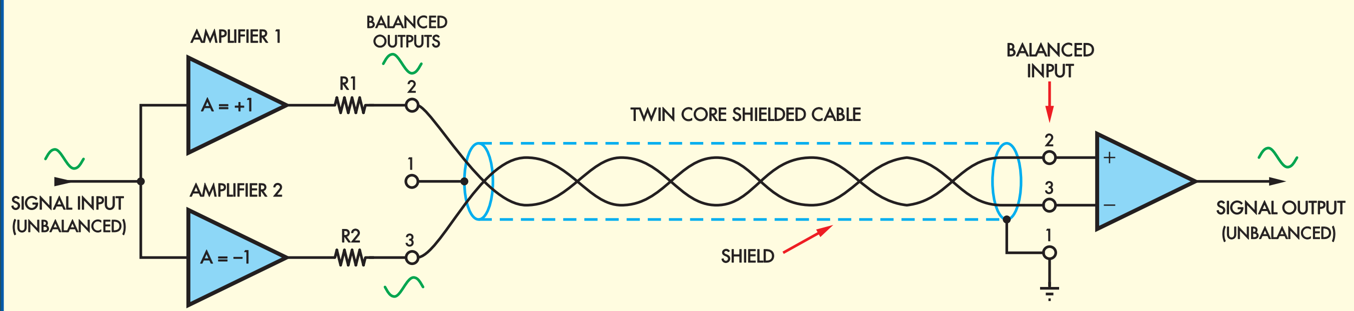


Fig.1: the basic arrangement for converting an unbalanced audio input signal to a balanced signal and back again.

still supply signal should one of the cores be shorted due to a wiring fault (or damage).

How it works

Refer now to Fig.2 for the full circuit details. As can be seen, it's based on three LM833 op amps (IC1-IC3).

Op amps IC1a, IC1b and IC2a make up the 'balanced input to unbalanced output converter' section. As shown, the balanced input signal is fed in via pins 3 and 2 of the XLR socket. These inputs are each tied to ground using a 100kΩ resistor to prevent the signal lines from 'floating' with no input connected.

From there, the audio signals are coupled via 10µF non-polarised (NP) electrolytic capacitors to pins 3 and 5 of op amps IC1a and IC1b respectively. The 220pF capacitor between the two inputs and the 100pF capacitors at pins 3 and 5 are included to filter RF (radio frequency) signals.

In addition, pins 3 and 5 are each tied to ground via a 10kΩ resistor to set the DC bias for IC1a and IC1b. These 10kΩ resistors either connect to the signal ground or to a half-supply ground, depending on the power supply configuration used.

IC1a and IC1b both operate as non-inverting amplifiers with a gain of 1, as set by their 10kΩ feedback resistors and resistor R1 (20kΩ). A 100pF capacitor across each 10kΩ feedback resistor rolls off high-frequency signals above about 160kHz.

The outputs from IC1a and IC1b appear at pins 1 and 7 respectively, and are summed in differential amplifier stage IC2a. For signals from IC1a, IC2a functions as an inverting amplifier – ie, it operates with a gain of –1. Conversely, for signals on its pin 3 input, it operates as a non-inverting amplifier with a gain of 2. Because of this, the signals from IC1b are divided by two using a 10kΩ resistive divider before being fed to IC2a.

This means that each signal path has overall unity gain through IC2a. However, IC2a inverts the signals from IC1a so that they are now in-phase with the signals from IC1b; as a result, both signals add to provide an overall gain of 2.

The resulting unbalanced signal appears at pin 1 of IC2a and is AC-coupled to the output via a 22µF NP capacitor and a 150Ω resistor. The 100kΩ resistor from the 22µF capacitor to ground ensures that the output signal swings above and below ground with no DC bias.

Unbalanced to balanced stage

A single LM833 dual op amp (IC3) is used for the 'unbalanced input to balanced output' stage. As shown, the audio input signal is AC-coupled via a

Specifications

- Signal-to-noise ratio: –100dB with respect to 1V output, 4.7kΩ input load.
- Frequency response: –3dB at 2Hz and 200kHz.
- Total harmonic distortion: less than 0.001% from 20Hz to 20kHz with a 1V input.
- Signal handling: supply dependent; requires 30V DC or ±15V for 9V RMS signal handling.

Parts List – Balanced/Unbalanced Converter

1 PC board, code 770, available from the *EPE PCB Service*, size 103 × 85mm
3 8-pin IC sockets
1 2.5mm PC-mount DC socket
2 3-way screw terminal blocks (5.08mm or 5mm spacing)
4 2-way screw terminal blocks (5.08mm or 5mm spacing)
4 M3 x 6.3mm tapped standoffs
4 M3 x 6mm screws
2 2-way pin headers (2.54mm spacing)
1 3-way pin header (2.54mm spacing)
3 jumper shunts
1 60mm length of 0.8mm tinned copper wire

Semiconductors
3 LM833 dual op amps (IC1-IC3)
2 15V 1W Zener diodes (ZD1,ZD2)
2 IN4004 1A diodes (D1,D2)

Capacitors
2 470µF 25V PC electrolytic
1 100µF 25V PC electrolytic
3 22µF NP electrolytic
1 10µF 16V PC electrolytic
3 10µF NP electrolytic
3 100nF MKT polyester
1 220pF ceramic
7 100pF ceramic

Resistors (0.25W, 1%)

6 100kΩ	1 4.7kΩ
1 20kΩ	4 150Ω
13 10kΩ	2 33Ω 0.5W

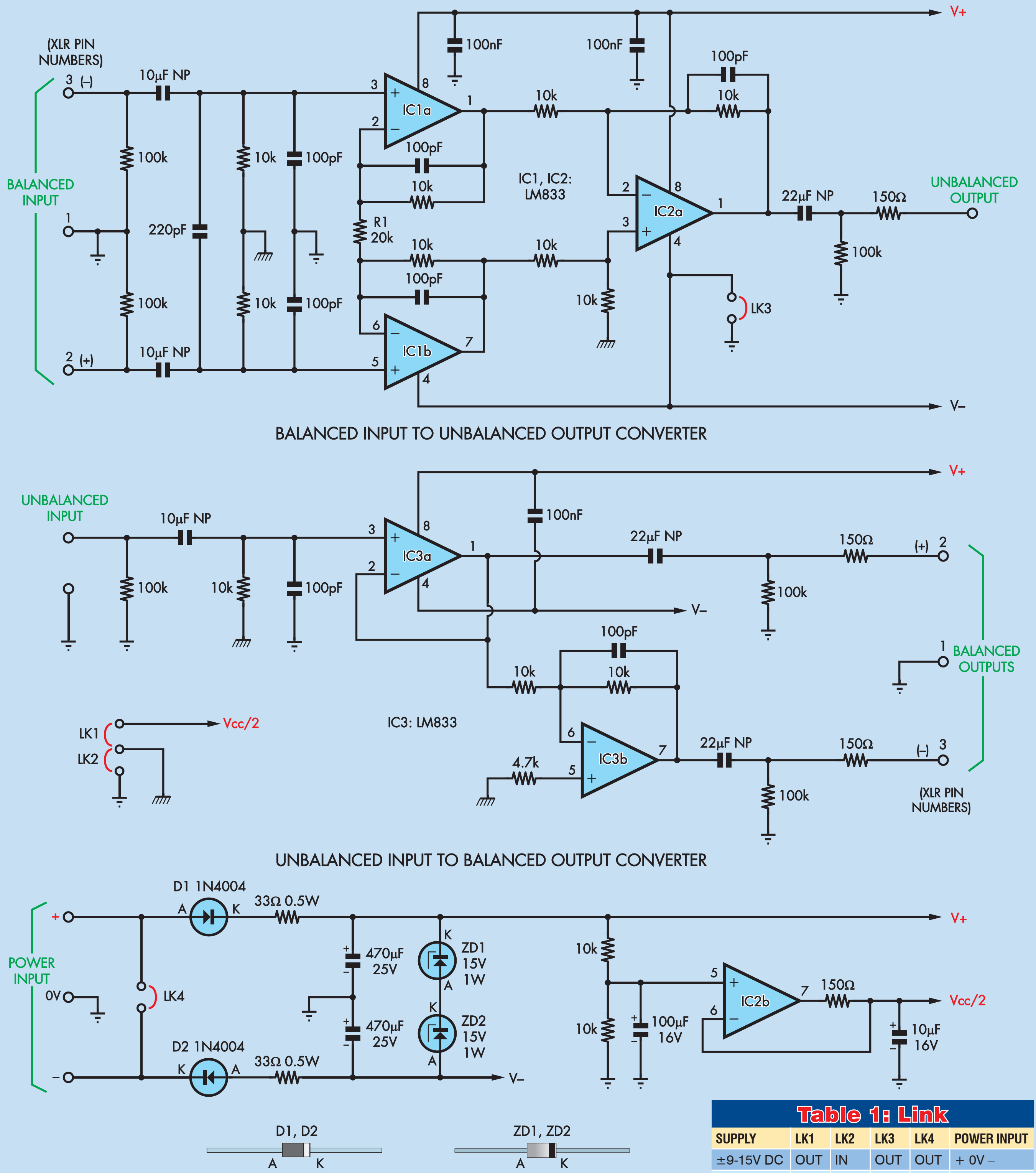


Table 1: Link

SUPPLY	LK1	LK2	LK3	LK4	POWER INPUT
±9-15V DC	OUT	IN	OUT	OUT	+ 0V –
7-12V AC	OUT	IN	OUT	IN	+ 0V
9-30V DC	IN	OUT	IN	OUT	+ 0V
Note: install LK4 for an AC supply only					

BALANCED/UNBALANCED CONVERTER

Fig.2: the circuit can be split into three sections: 1) a balanced input to unbalanced output converter (top); 2) an unbalanced input to balanced output converter (centre); and 3) the power supply circuit (bottom).

10μF NP capacitor to the non-inverting input (pin 3) of IC3a. A 100pF capacitor shunts any RF signal to ground, while the associated 10kΩ resistor sets the DC bias for IC3a.

Note that this 10kΩ resistor either connects to the signal ground or to a half-supply ground, depending on the power supply configuration used (this is the reason for the different earth symbol at the bottom of this resistor). The 100kΩ resistor at the input ties the input line to ground when no signal is connected.

IC3a is wired as a unity-gain buffer stage and so its pin 1 output follows the signal input. The non-inverting (+) component for the balanced signal is then AC-coupled via a 22μF NP capacitor and a 150Ω resistor to pin 2 of the XLR output socket.

The 150Ω resistor isolates IC3a's output from external capacitive loads, to ensure stability. The 100kΩ resistor on the output side of the 22μF capacitor ensures that the signal swings symmetrically above and below ground.

The out-of-phase signal is derived using IC3b. This stage is also fed from pin 1 of IC3a and functions as an inverting amplifier with a gain of –1, as set by its 10kΩ feedback resistor. As before, a 100pF capacitor across the feedback resistor shunts any frequencies above 160kHz to prevent amplifier oscillation.

IC3b's output at pin 7 is inverted compared to IC3a's output. It drives pin 3 of the XLR socket via another 22μF capacitor and 150Ω resistor combination.

Note that the pin assignments on the XLR socket follow standard practice. Pin 1 is the ground, while pin 2 is for the 'hot' or non-inverted (+) signal and pin 3 is for the 'cold' or inverted signal.

Power supply

Power for the circuit can come from a 9V to 30V DC source, a ±9V to 15V DC source or a 7V to 20V AC source. The current requirements are quite modest at just 30mA.

The simplest supply arrangement is to use a ±9V to 15V DC source (this type of supply can often be found in existing equipment). The positive rail is simply connected to the '+' supply input, the negative rail to the '–' input and the ground to 0V. Diodes D1 and D2 provide reverse polarity protection, while two 470μF capacitors filter the supply rails.

Zener diodes ZD1 and ZD2 protect the op amps by conducting if the input voltage rails exceed ±15V. A 33Ω

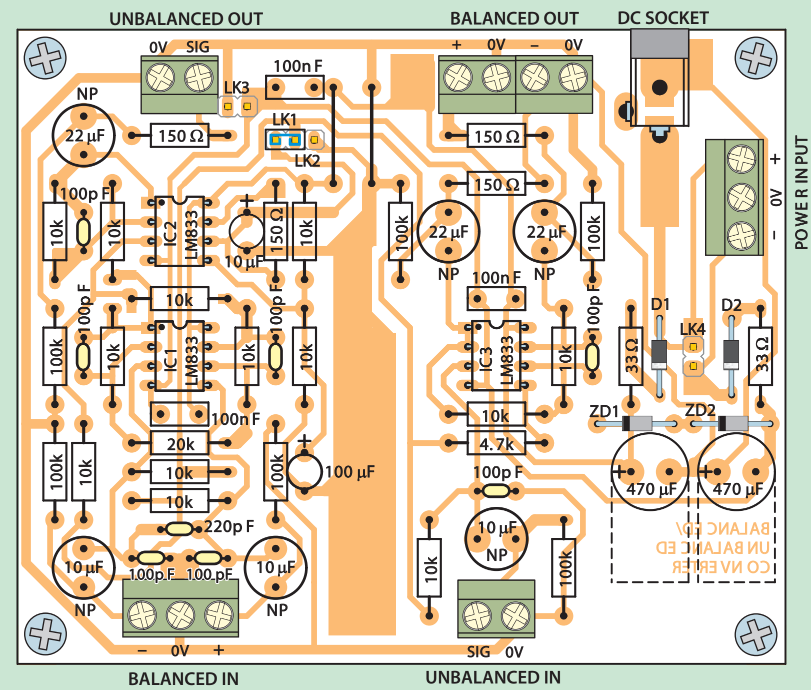


Fig.3: install the parts on the PC board as shown in this parts layout diagram. Table 1 (facing page) shows how to install links LK1-LK4 to suit the selected power supply.

resistor in series with each supply line limits the current through ZD1 and ZD2 when they conduct, **but note that voltages above ±18V may destroy these Zener diodes.**

With this supply arrangement, the two different grounds on the circuit are tied together using link LK2 (see Table 1). This biases the op amp inputs at 0V so that the signal swings above and below ground.

AC supply

A 7V to 12V AC supply can also be used to derive positive and negative supply rails. In this case, the '+' and '–' inputs are connected together using link LK4 and the supply is connected between either of these two inputs and the 0V (ground) terminal.

With this supply configuration, diodes D1 and D2 function as half-wave rectifiers, with filtering provided by two 470μF capacitors. D1 conducts on the positive half-cycles to derive the positive rail, while D2 conducts on the negative half-cycles to derive the negative rail.

As before, the two grounds are connected using link LK2.

Complication

The circuit is a little more complicated for a 9V to 30V DC supply. That's because the signal can no longer swing below the 0V rail, since there's no negative supply. As a result, the op amps must be biased to a mid-supply voltage, so that the signal can swing symmetrically about this voltage.

This mid-supply voltage is produced using a voltage divider consisting of two 10kΩ resistors between the V+ rail and ground. A 100μF capacitor filters this half-supply rail, which is then fed to IC2b pin 5.

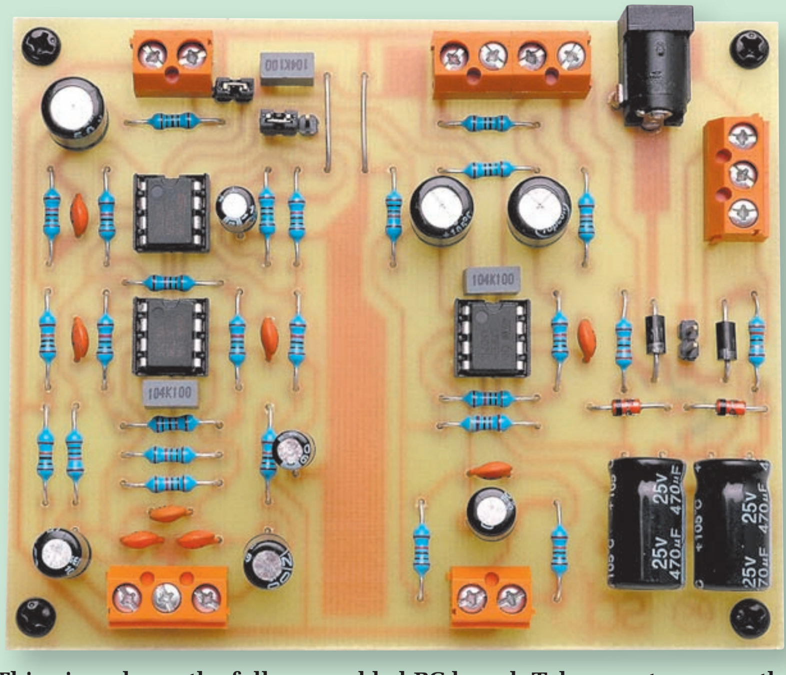
Op amp IC2b is wired as a unity-gain buffer stage. Its pin 7 output drives a 10μF capacitor via a 150Ω decoupling resistor to produce the Vcc/2 half-supply rail to bias the op amps in the converter stages.

In this case, links LK1 and LK3 are installed. Link LK1 connects the Vcc/2 rail to the junction of the 10kΩ bias resistors on the pin 3 and pin 5 inputs of IC1a and IC1b. It also connects the Vcc/2 rail to the pin 3 input of IC3b via another 10kΩ resistor. Link LK3 connects the negative supply pins for the op amps to ground.

Finally, the AC coupling capacitors at the inputs and outputs of the various op amps remove any DC component from the signal.

Building it

The assembly is straightforward with all the parts installed on a PC board



This view shows the fully-assembled PC board. Take care to ensure that the semiconductors and electrolytic capacitors are correctly installed.

coded 770. This board is available from the *EPE PCB Service*. The printed circuit board component layout is shown in Fig.3. The board also carries screw terminal blocks for the audio input and output connections, plus a DC socket for the power supply connections (depending on the supply used).

Begin construction by checking the board for any defects such as shorted tracks or breaks in the tracks. Check also that the hole sizes for the DC socket and screw terminal blocks are correct by test fitting these parts and check that the four corner mounting holes are drilled to 3mm.

Install the two wire links first, followed by the resistors. Table 2 shows the resistor colour codes, but you should also check each resistor using a DMM before soldering it in place, as some colours can be difficult to decipher.

The diodes and Zener diodes can go in next, followed by the three IC sockets. Take care to ensure that these parts are all oriented correctly and be sure to use the correct diode at each location. We recommend that you use IC sockets and leave the ICs out until you have completed the supply voltage checks.

The capacitors are next on the list. Take care with the electrolytic types, as they must all be fitted with the correct polarity. The two 470µF capacitors are mounted on their sides, with their leads bent down through 90° so that they pass through the holes in the board.

Finally, install the pin headers (for the links), the DC socket and the screw terminal blocks. The 4-way screw terminal blocks are made by sliding two 2-way terminals together, using the dovetail mouldings on either side.

Installation

As mentioned earlier, there are several supply options for the Balanced/Unbalanced Converter. The current requirements are quite low at 30mA maximum when each output is driving a 1V signal into 600Ω.

Installation is basically a matter of deciding which type of supply you want to use and then choosing the linking options – see Table 1. **Note that link LK4 is installed only for an AC supply.**

A 9V to 30V DC supply can be connected either via the DC socket or via the '+' and 0V terminals on the 'Power Input' screw terminal block. An AC supply is connected in exactly the same manner (ie, via the DC socket or between the '+' and 0V terminals).

For the ±9V to 15V DC supply option, connect the positive lead to the '+' terminal, the negative lead to the '–' terminal and the 0V lead to the 0V terminal. Again, make sure the links are correct – see Table 1.

Apply power and check that close to the supply voltage appears between pins 8 and 4 of the ICs. If the supply is 12V DC, for example, then the pin 8 to pin 4 voltage should be close to 10.3V (after allowing for a 1.7V drop across D1 and its series 33Ω resistor). The Vcc/2 supply, as measured at pin 6 of IC2b and at the pin 1 and pin 7 outputs of the other op amps, should be close to 10.3V/2 or 5.15V.

For an AC supply, the pin 8 voltage should be positive with respect to ground, and the pin 4 voltage negative. The actual voltages should be about 1.414 times the AC voltage, minus about 1.7V for the diode and resistor drop.

Thus, for a 9V AC supply, the voltage should be about 12.7V – 1.7V = 11V DC. This means that there should be +11V with respect to ground on pin 8 of each IC, and –11V on pin 4 of each IC.

Finally, for a ±9V to 15V DC supply, the pin 8 and pin 4 voltages should be about 1.7V less than the input voltages. For example, if the supply is ±12V DC, there should be about +10.3V on pin 8 of each IC and –10.3V on pin 4 of each IC *EPE*

Table 2: Resistor Colour Codes

❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	6	100kΩ	brown black yellow brown	brown black black orange brown
❏	1	20kΩ	red black orange brown	red black black red brown
❏	13	10kΩ	brown black orange brown	brown black black red brown
❏	1	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❏	4	150Ω	brown green brown brown	brown green black black brown
❏	2	33Ω	orange orange black brown	orange orange black gold brown

Total harmonic distortion (THD)

FREQUENT *EPE Chat Zone* contributor **741**, recently posted the following question about measuring total harmonic distortion (THD) and observing a signal's spectrum using a fast Fourier transform (FFT).

(1) Inspired by an article I read, I'm interested in building a Wien-bridge oscillator, measuring the distortion, then trying to minimise the distortion. Does anyone know a way to accurately measure THD using normal workshop instruments (scope, multimeter)?

(2) Related question: On LT Spice I placed an ideal sine generator, then chose View/FFT. I noticed the wide 'skirts' leading up to the peak at the sine frequency. I wondered what determines the sharpness of the peak.

In order to answer these questions, it is useful first to look at exactly what we mean by 'total harmonic distortion' (THD). This inevitably depends on some advanced mathematics, for which we will include quite a few of the relevant equations, however it should be possible to follow the bulk of this article even if you are not familiar with (or have forgotten) the more advanced maths.

Distortion

Distortion is an unwanted effect which causes the shape of the waveform at the output of a linear circuit to be different from what it ideally should be. The word *linear* is critical here. A linear circuit is one in which the output is related to the input by multiplying by a simple scaling factor G_1. So, for an input signal, v_{in}, we could write the output signal, v_{out}, as:

$$v_{out} = G_1 v_{in}$$

If G_1 is greater than 1, we refer to the circuit as an amplifier with a gain of G_1. The term linear makes sense if you plot a graph of this relationship between v_{in}, and v_{out}; it is a perfect straight line (red graph) going through the origin, as shown in Fig.1. Any circuit for which the input-output graph is not a straight line is non-linear and will introduce distortion.

The question from 741 actually referred to an oscillator, which does not have an input in the conventional sense, although it is an amplifier in a feedback loop. However, it does have an ideal output waveform shape, and therefore it is possible to measure the distortion with respect to this ideal. For the purpose of defining THD though, it is easier to develop ideas in terms of amplifiers.

Returning to our ideal linear amplifier: $v_{out} = G_1 v_{in}$, we may find that a real circuit has a reasonably good linear response, but there is a DC offset (or DC error) on the output. We would then write the equation as:

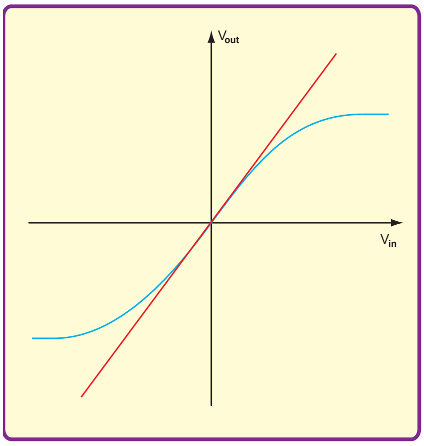


Fig.1. Input/output (red) relationship for an idealised linear circuit – no distortion. Example of a nonlinear input/output (blue) relationship graph of a real amp – with some distortion from large input signals

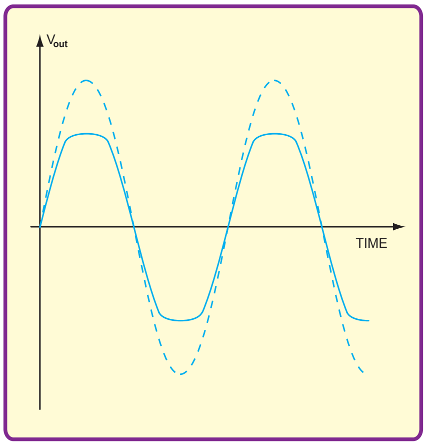


Fig.2. This shows the distorting effect of an input-output relationship like that shown in Fig.1. The ideal output is shown by the dotted line; the actual output (solid line) is clipped or compressed

$$v_{out} = G_0 + G_1 v_{in}$$

where G_0 is the offset. Although this 'changes the shape of the output waveform' it is not of primary concern when considering distortion. The graph is still a straight line, although it no longer goes through the origin.

Clipping

There are a number of reasons why an amplifier might not have a completely linear response, but perhaps the most obvious is that its output signal level is limited. This limit will typically depend on the supply voltage. The input-output relationship for a real amplifier with finite maximum output is also shown in Fig.1 (blue curved graph). The effect on an input waveform is shown in Fig.2 and referred to as *clipping*; it may also be called *compression*, particularly where the limiting is 'softer' or more specifically controlled.

For an amplifier with limited output, the input-output relationship may be very close to a straight line if the input signals remain small. For this reason, circuits which have to produce large output signals, such as power amplifiers, are more likely to exhibit high distortion, at least due to clipping or compression.

If our amplifier does not have a straight-line input-output relationship then we are presented with the problem of how we might represent the output mathematically in order to determine how much distortion is present. We could proceed with a very detailed analysis of the circuit, taking into account the characteristics of all the components, but this may be very difficult, and may produce an equation which is too unwieldy to work with. It would also only be applicable to the one circuit we had analysed, and we would have to start again from scratch for each new circuit.

In theory

We need something which is more general and can represent the output of any circuit producing distortion. Our answer is provided by Taylor's theorem, which was published in 1715 by English mathematician Brook Taylor, although the Scottish mathematician James Gregory had actually discovered the same thing back in 1671.

Put in simple terms, the theorem states that any a smooth mathematic function can be approximated by a polynomial (know as a Taylor series). By smooth function we mean something for which we can draw a smooth curve on a graph. The full definition and conditions for Taylor's theorem are, of course, more rigorous and specific and can be found in appropriate maths textbooks and internet sites.

A *polynomial* is an equation formed from a sum of powers of our variable of interest (in this case v_{in}). By powers we mean the original v_{in} (power 1), v_{in} squared (power 2), v_{in} cubed (power 3), v_{in} to the power 4, and so on. Each power is scaled by a different amount (G_1, G_2, G_3 etc) in which the numerical subscript refers to the relevant power of v_{in}. We may also include a DC offset G_0. This leads to a completely general output equation for our amplifier output with distortion, which is a natural extension of the ideal linear amplifier equation given above.

$$v_{out} = G_0 + G_1 v_{in} + G_2 v_{in}^2 + G_3 v_{in}^3 + G_4 v_{in}^4 + \ldots$$

The *G* values are referred to as *coefficients* and the items which we are adding up, eg $G_1 v_{in}$ and $G_1 v^2_{in}$, are referred to as *terms*. In principle there could be a very large number of terms, but in practice the values of the coefficients get very small for higher powers of v_{in} and we are unlikely to need anything beyond the G_5 term to calculate THD.

Now we can separate v_{out} into three components: the offset, the ideal output signal and the distortion; these are:

DC offset	G_0
Ideal output	$G_1 v_{in}$
Distortion	$G_2 v_{in}^2 + G_3 v_{in}^3 + G_4 v_{in}^4 + \ldots$

If we knew v_{in} and all the coefficients, we could work out the relative level of ideal signal and distortion and so find the percentage of distortion in the whole output signal. This leads us immediately to a couple of problems: we have not defined v_{in} and we do not know the coefficients.

We are likely to want to compare different circuits to see which design produces least distortion. This is only meaningful if it can be done in a consistent way; it therefore makes sense to use the same type of signal for v_{in} in such a comparison, and indeed for all distortion figures. The special properties of sinewaves make them the perfect choice as the basis of distortion measurement.

Adding at set sinewaves of the *same frequency* produces another sinewave at that frequency, even if the phases (relative time shift) of the sinewaves are not equal. This is not true for any other periodic (repeating) waveform. Furthermore, any waveform can be formed by adding together a set of sinewaves of various frequencies and different amplitudes. This 'sum of sinewaves' is known as a *Fourier series* and was developed by Jean Baptiste Joseph Fourier (1768–1830), a French mathematician and physicist, while researching mathematical modelling of heat transfer.

For example, a square wave may be described as being at 1kHz, but this is just the *fundamental frequency*; there are other frequencies present too. For the 1kHz square wave the sinewaves which can be added together to form it are approximately (first figure is amplitude) 1.27 at 1kHz, 0.42 at 3kHz, 0.25 at 5kHz, 0.18 at 7kHz and so on to infinity

Spectrum analysis

Looking at this the other way round, we can break any waveform down into its constituent sinewaves, finding the amplitude of each one. Doing this is called Fourier analysis and one technique for achieving this is the fast Fourier transform, mentioned by 741 in the second part of his question. If we plot a graph of the amplitude of the constituent sinewaves along a frequency axis we have the spectrum of the waveform. Part of the spectrum of a square wave is shown in Fig.3.

If we apply a sinewave input to a perfect linear amplifier we will get a sinewave of the same frequency at the output. The spectrum of both input and output will contain a single frequency component. If the amplifier introduces any distortion then the output wave shape will no longer be a perfect sinewave and therefore must contain additional constituent sinewaves at frequencies other than the input frequency.

Fourier analysis will reveal these frequencies in the output spectrum. This allows us to separate the ideal and distorted parts of the signal, just as we did in the generalised equation above (this is illustrated in Fig.4). However, now we have a practical way of doing this, assuming we have instruments or simulation tools which can find a signal's spectrum for us; which of course we do.

Now we have selected v_{in} as a sinewave, we can proceed with using our general output equation to calculate the distortion. To keep things simple, initially we will assume that the only distortion term present in our output is the v_{in} squared term, $G_1 v^2_{in}$. We will also ignore the DC error. We will use a cosine input signal, as this is a bit more convenient in terms of the calculations than a sine, but the basic properties in terms of spectra are the same.

So we have:

$$v_{out} = G_1 v_{in} + G_2 v_{in}^2$$

and

$$v_{in} = V_m \cos(\omega t)$$

Where V_m is the peak amplitude of the cosine input wave, ω is its frequency in *radians* per second and *t* is time. Substituting the v_{in} expression into the v_{out} equation gives:

$$v_{out} = G_1 V_m \cos(\omega t) + G_2 V_m \cos^2(\omega t)$$

To deal with the $\cos^2$ term we use one of the basic trigonometric identities known as the *double angle formulae*, which are related to Pythagoras' theorem. Again, details of the maths can be found in suitable texts or maths internet sites under 'double angle' or 'compound angle' formulae. Specifically, we need to use:

$$\cos(2X) = 2\cos^2(X) - 1$$

or

$$\cos^2(X) = \tfrac{1}{2}(1 + \cos(2X))$$

So our equation becomes:

$$v_{out} = G_1 V_m \cos(\omega t) + \tfrac{1}{2} G_2 V_m + \tfrac{1}{2} G_2 V \cos(2\omega t)$$

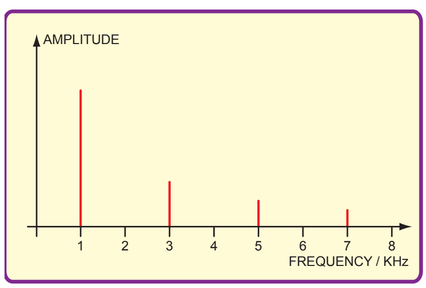


Fig.3. Part of the spectrum of a square wave

Here $\frac{1}{2}G_2 V_m$ is a DC voltage (there is no cosine or other frequency-dependent value in this term). This will add to any existing DC offset (which we ignored earlier). Of more interest is the term $\frac{1}{2}G_2 V_m \cos(2\omega t)$, which represents a signal at *twice* the original frequency (2ω).

As we are looking for general equations, the details of the coefficients such as $\frac{1}{2}G_2 V_m$ are not of particular interest at the moment and we can tidy up the equation using $B_2 = \frac{1}{2}G_2 V_m$, and similarly for other terms.

$$v_{out} = B_0 + B_1 \cos(\omega t) + B_2 \cos(2\omega t)$$

To obtain this equation we started with a simplified version of our distorted output signal in which we only included the $G_1 v^2_{in}$ term from the distortion. If we include more distortion terms the calculation proceeds in the same way – we use relevant trigonometric identities to deal with the various powers of cosine. There is a lot more work to do as the equations get bigger, but the result comes out in a well structured form:

$$v_{out} = B_0 + B_1 \cos(\omega t) + B_2 \cos(2\omega t) + B_3 \cos(3\omega t) + B_4 \cos(4\omega t) + \ldots$$

Remember this is the output from a distorting amplifier with a single sinewave (specifically a cosine in this case) at the input. Just as we did with our general output signal, we can separate v_{out} into three components: the offset, the ideal output signal and the distortion; these are:

DC Offset	B_0
Ideal output	$B_1 \cos(\omega t)$
Distortion	$B_2 \cos(2\omega t) + B_3 \cos(3\omega t) + B_4 \cos(4\omega t) + \ldots$

We see that the distortion consists of a set of sinewaves (cosines) at frequencies of twice (2ω), three times (3ω), four times (4ω), and so on times the input frequencies. Frequencies which are whole-number multiples of a particular frequency are called *harmonics* of that fundamental frequency. This result shows us that for a sinewave input, the distortion is entirely due to harmonics of the input signal, which is why we use the term *harmonic distortion*.

If our input signal is more complex than a single sinewave, then the distortion will contain frequencies other than the harmonics. For example, if the input signal contains two sinewaves of different frequencies (ω_1 and ω_2), then the distortion will include, in addition to the harmonics of both frequencies, the sum ($\omega_1 + \omega_2$) and difference ($\omega_1 - \omega_2$) frequencies, and other combination frequencies. This is known as *intermodulation distortion*. Intermodulation distortion is of particular importance in radio receiver circuits.

The term $B_2\cos(2\omega t)$ in the equation above tells us the signal level of the second harmonic distortion, but on its own it is not very useful because what we really need to know is how large the distortion is in comparison with the ideal output. We therefore define the *second harmonic* distortion, D_2, as:

$$D_2 = \frac{|B_2|}{|B_1|}$$

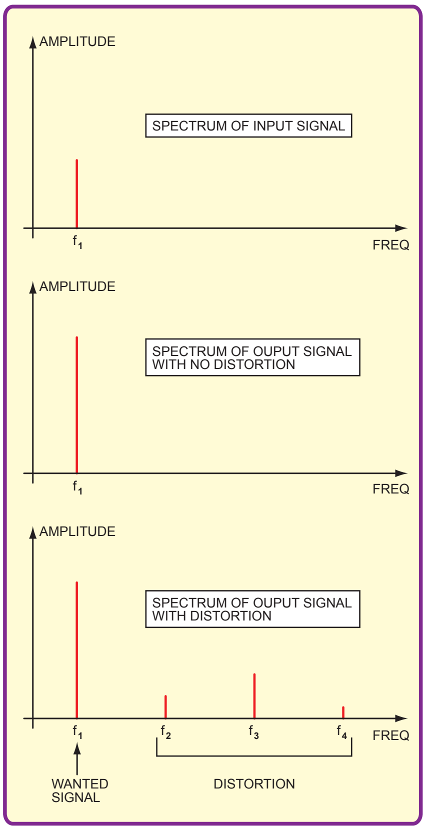


Fig.4. If we apply a single input frequency to a distortion-free linear circuit the output signal will also only contain that single frequency. Distortion will however, introduce additional frequencies in the output spectrum

In this equation the vertical lines around the *B* terms indicate that we are looking at the magnitude of the B values, for example |-4| is just 4, we ignore the sign. We can multiply D_2 by 100% to express the second harmonic distortion as a percentage of the ideal output. We can also define distortion values for the other harmonics in a similar way:

$$D_3 = \frac{|B_3|}{|B_1|} \qquad D_4 = \frac{|B_4|}{|B_1|} \qquad \text{and so on.}$$

Terms such as $B_2\cos(2\omega t)$ are time dependent and actually show the level of that distortion component at each instant of time. When comparing circuits, it is more useful to know the average distortion over time. The average voltage of a zero-offset sinewave is zero, so this will not help. A similar issue exists in terms of finding the average power of an AC signal, for which we use *Root Mean Square* or RMS values. It is worth digressing from our distortion discussion to recall the definition of RMS signal values and associated AC power calculations.

Digression

The power dissipated in a resistor when a constant voltage (DC) is applied is easy to calculate. It is

$$P = IV = I^2R = V^2/R$$

Because the voltage, current and resistance are constant in this situation, the average power dissipation is equal to the power dissipated at any instant. However, when we have any form of varying voltage or current (AC) the situation is more complicated. The power dissipated in a resistor driven by an AC wave varies from instant to instant in accordance with the equations above, but the formula does not tell us what the average power dissipated over a period of time is.

To work out the power for an arbitrary cyclic waveform we need to add up all the contributions for instantaneous power and average them over the cycle. To find the average height of a number of people you measure the height of each, add up all the heights and divide by the number of people. To find the average of the power it would seem to follow that we take V^2/R for each instant of the waveform, add them all up and divide by the number of instants.

Unfortunately, there are an infinite number of instantaneous power values – the current varies continuously, unlike people where there are a finite number of individuals. To solve this problem we need to use some calculus, specifically integration, to find our average power. The average power dissipated in a resistor, *R*, for a cyclically varying voltage, *v*, over the cycle time, *T*, of a waveform is given by the equation below. We integrate (indicated by the symbol ∫) the waveform over one cycle (0 to *T*) to add up all the instantaneous contributions and divide by *T* (hence 1/*T* in the equation) to get the average. The *dt* in the equation represents an instant of time (*t*).

$$P = \frac{1}{T}\int_0^T \frac{v^2}{R}\,dt$$

If we compare this formula with $P = V^2/R$ for DC we can find a value of DC current which would give the *same heating effect* (power dissipation) as *v* averaged over one cycle. This is obtained by multiplying the above equation by *R* and then taking a square root (if this is hard to follow, note we would get *V* if we did the same to V^2/R , which is our DC power value). The result is:

$$V_{RMS} = \sqrt{\frac{1}{T}\int_0^T v^2\,dt}$$

This is the RMS value of the AC voltage, for which power $P = V^2_{RMS}/R$. The voltage is being *squared* (v^2 in the equation), averaged by integration (hence *mean*) and square-rooted (the √ in the equation) – this is where the name comes from. We can define an RMS current in a similar way.

If we have a sinewave, then $v = V_m\sin(2\pi t/T)$ where *t* is time and V_m is the peak (maximum) instantaneous value of the AC voltage. We have to do some more maths – substitute the sinusoidal current into the equation above and perform the integration. We will not go into the details here, but we get $V_{RMS} = V_m/\sqrt{2}$ or $0.707V_m$.

We can now return to our distorted signal and consider the power and RMS values. The wanted output signal is $v_1 = B_1\cos(\omega t)$ so its RMS value is $v_{1,RMS} = B_1/\sqrt{2}$. From this we can find the power of the ideal output signal, P_1:

$$P_1 = \frac{v_{1,RMS}^2}{R} = \frac{B_1^2}{2R}$$

Similarly, we can find the power of the second harmonic output and then the ratio of the two and hence the second harmonic distortion D_2.

$$P_2 = \frac{B_2^2}{2R} \qquad \frac{P_2}{P_1} = \frac{B_2^2}{B_1^2} = D_2^2$$

It would be useful to know the total power of the distortion and compare this with the wanted signal. We might be tempted to simply go ahead and add up P_2, P_3, P_4 etc. to get the total power. A mathematician might object at this point and say that what we can do in terms of finding the power of a single signal might not work when we have a whole set of them (the distortion spectrum). Fortunately, it can be shown, using something called *Parseval's Theorem*, that we can add up these power values. Parseval's Theorem shows that we can work out the power or energy of a signal using its spectrum (Fourier series) or the original signal and get the same answer.

The total power of the distortion, $P_D = P_2 + P_3 + P_4 + ...$, is, therefore:

$$P_D = \frac{B_2^2}{2R} + \frac{B_3^2}{2R} + \frac{B_4^2}{2R} + ..$$

Dividing by the power of the wanted signal gives:

$$\frac{P_D}{P_1} = \frac{B_2^2}{B_1^2} + \frac{B_3^2}{B_1^2} + \frac{B_4^2}{B_1^2} + ..$$

$$\frac{P_D}{P_1} = D_2^2 + D_3^2 + D_4^2 + ..$$

Representing the overall distortion with single value, *D*, we can write:

$$D^2 = \frac{P_D}{P_1} = \frac{P_2 + P_3 + P_4 + ...}{P_1}$$

D is the *total harmonic distortion (THD)* and is defined in terms of the individual harmonic distortions by:

$$D = \sqrt{D_2^2 + D_3^2 + D_4^2 + ...}$$

As power is proportional to the square of the voltages concerned, we can also write the THD as:

$$D = \frac{\sqrt{P_D}}{\sqrt{P_1}} = \frac{\sqrt{v_2^2 + v_3^2 + v_4^2 + ...}}{v_1}$$

In which the v_1 is the amplitude (or RMS) value of the fundamental and v_2, v_3 etc are the amplitudes (or RMS) values of the distortion products.

Unfortunately, this is not the only definition of THD in use. The alternative approach is to define D directly as the power ratio P_D/P_1.

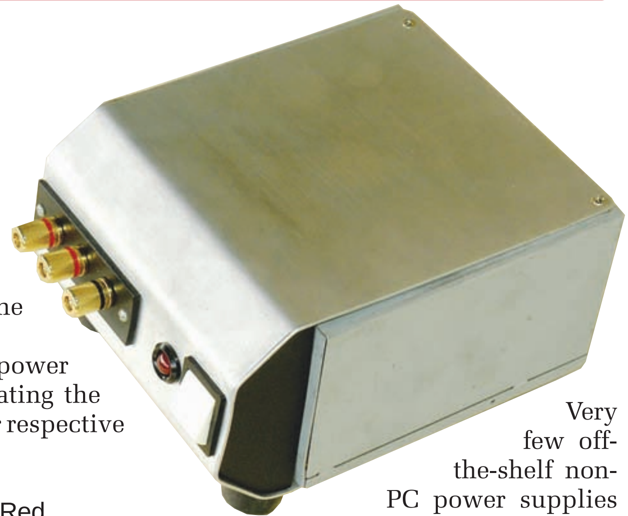
Next month, we will continue to look at further aspects of distortion and signal spectra and address 741's questions more directly.

Recycle It!

BY JULIAN EDGAR

www.julianedgar.com

Low cost 5V/12V Power Supply



Very few off-the-shelf non-PC power supplies are fan-cooled.

IF YOU have an old PC power supply around the place, chances are you can make a 5V / 12V bench-top power supply for nearly nothing. Here's how to do it.

Starting point

My starting point was a salvaged 'Max Power' 200W AT power supply (see below). Nearly every discarded PC that you find will have a power supply in it – and PCs are available for peanuts at garage sales, secondhand stores, computer fairs and so on.

This type of power supply has a pre-wired mains-power on/off pushswitch, whereas more recent supplies require the PC to tell the power supply that all is well before switching on, even after the button is pushed. That makes the older AT supply much more suitable for this type of standalone application.

One way of identifying the AT type of supply is to look for the two plugs shown in the photo bottom right – one's got P8 on it and the other has P9.

There is a label on the power supply I salvaged indicating the output voltages and their respective wiring colour codes:

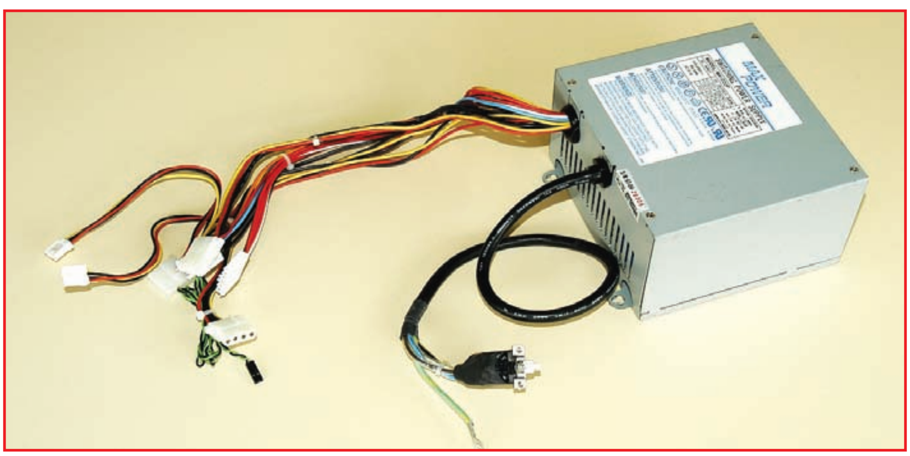
+5V	20A	Red
+12V	8A	Yellow
–12V	0.5A	Blue
–5V	0.5A	White

Most power supplies will use these same colour codes for the voltages, while some power supplies will be able to supply even more current than these figures. (But always check the voltage outputs with a multimeter to confirm things are as they should be.)

One of the benefits of using a PC power supply (besides cost, that is!) is that it comes equipped with a built-in fan. This particular unit is labelled 'Smart Fan' so we assume that the fan is varied in speed as the conditions require it.

If you salvage a power supply you'll then need to come up with the cord

PC power supply with built-in fan



The author's Max Power 200W AT power supply rescued from a discarded PC

Look for the annotations P8 and P9

that has the IEC plug at one end and a mains power plug at the other. You should find plenty wherever you got your old PC from!

Getting started

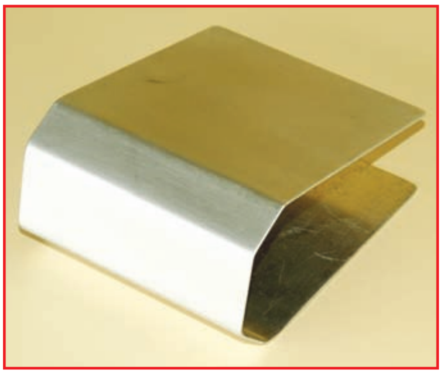
The approach that I adopted was to make a new ‘snout’, or U-shape faceplate ‘shroud’ for the power supply box. This was folded up from a single piece of 2mm thick aluminium. As seen here, the sheet is a fraction narrower than the power supply – but that is only because we had an offcut that size. Normally, you’d make the new section the same width as the power supply.

I used a home-made sheet metal folder to do the bending, but some blocks of wood and a vice could have been used to achieve the same end result. The top and bottom of the new piece should fit snugly against the top and bottom of the power supply. You may want to make the front extension a little longer than the 30mm that I used – in my case things got a little snug behind the new face.

You’ll need some binding posts – the number to match how many different voltage outputs you choose to have, plus the ground post. I chose three – +12V, +5V and ground.

Like many binding posts, they need to be mounted on an insulated strip if there isn’t to be a short-circuit between them and the box. A piece of scrap black plastic was used for this purpose. Because the current that can be carried is fairly large, I used two solder lugs on each binding post and soldered these together.

A slot was cut into the aluminium faceplate so that the rear of the binding posts stayed insulated from the box – there needs to be clearance between the terminals and the box, as well as between each terminal. At this stage four more holes were also drilled – one for a pilot LED and another large one for the switch. The two smaller ones are for the screws that hold the switch in place. Oh yes – and see those other two holes at the back? They’re so that the upper part of the plate can be attached to the power supply, using the two screws that are already there.



The U-shaped 2mm thick aluminium faceplate

The terminal strip mounted on the U-shaped faceplate. The two larger holes on the right are for the LED and mains switch

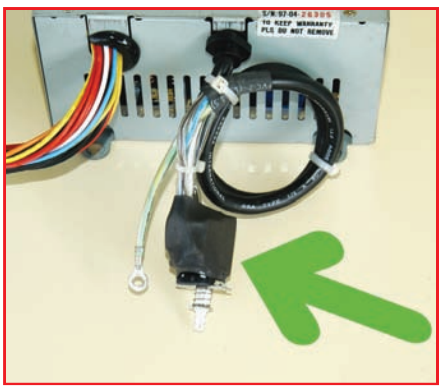
Screw terminal posts mounted on a strip of insulating material

The multicoloured output voltage leads minus their connectors. Gather the leads together in colour groups – all blacks, all reds, and so on

Let wiring commence

The next step is to do the wiring. This includes the power switch, which should now have its cable neatly bundled up so that it will fit behind the faceplate – there should be no need to cut this cord.

Note that the back of the switch is at mains voltage – the insulation around here (arrowed in the photo) should be improved with additional heatshrink, and great care must be taken to ensure that this area is inaccessible and that these terminals do not touch the case when the power supply is finished. The earth lead (green with the eye terminal on it) will be connected later – so don’t bundle it away.



Power switch cable bundled up to fit behind the faceplate. Note the ‘earth’ lead. The switch contacts MUST be insulated with additional heatshrink tubing

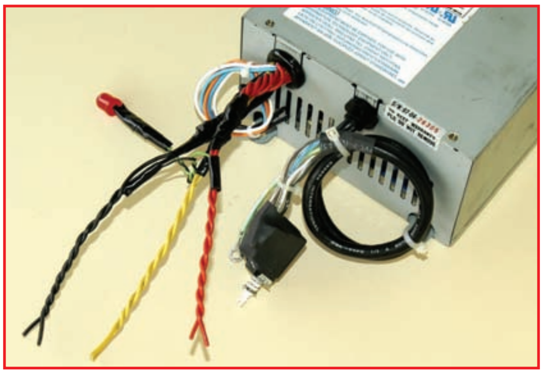
At this stage, you shouldn’t have touched any of the multicoloured wiring – the stuff that feeds out those output voltages that you want. But cutting is about to begin…

Cut all the plugs off then gather all the ‘like’ colour wires into separate bundles – so all the blacks together, all the reds together, and so on.

Solder all of the wires of each colour together, joining them to just two wires of the same colour. This step will reduce the number of wires from about 30 to six!

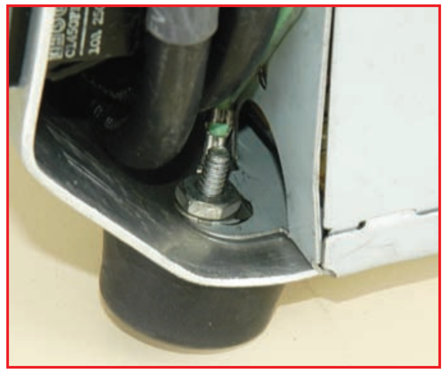
Two wires – rather than one – are used on each output to give better current carrying capacity. If you expect to be using the power supply near to its rated maximum a lot, you could use three or four wires going to each binding post, rather than two.

Note the blue (–12V), white (–5V) and orange (‘power good’) wires were not used in this design. However, if you



Solder together all of the wires of each colour group, joining them to just two leads of the same colour. Note the blue, white and orange leads were not used and are bundled seperately

A 10mm red LED was used as the 'power-on' indicator. If you use anLED, make sure you use a 560Ω series ballast resistor – see text



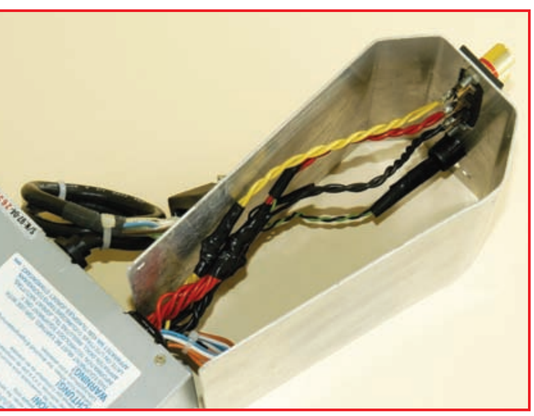
Bolting the 'earth eyelet' under one of the front feet fixings. Make sure it contacts the faceplate surface

want the –5V and –12V supplies, just add more binding posts and bring these supplies out to the faceplate.

It's a good idea to place fuses in the supplies. This is as easy as wiring in-line fuseholders into the 12V and 5V supply cables that you've just constructed. However, the power supply itself is protected by a fuse (and some supplies also have auto shutdown protection), so I didn't bother – I'll just be careful when I am using the supply!

I decided to use a 10mm red LED as the 'power on' indicator. Why such a large LED? Only because I had it around and I like large LEDs! You could use a 12V pilot lamp if you want, but if you use an LED make sure that you put a 560Ω resistor in series with it, then wire it to the 12V supply, with the long lead of the LED going to the positive.

This is what your project should look like at this stage – the mains power cord tidied up; the 12V, 5V and earth leads brought down in number to just a pair for each; the white, orange and blue leads insulated and bundled away; and the LED wired up – see photo top left.



Wiring to the rear of the new U-shaped faceplate, prior to sliding it over the PC power supply

Faceplate wiring

The next step is to bring the faceplate up close to the power supply and solder the 12V, 5V and earth leads to their appropriate binding posts. Push the LED through the front panel and mount the mains power switch. Make absolutely sure that the rear of the mains power switch remains well-insulated, with no possibility of the switch terminals touching the case or being accessible to fingers.

Unfortunately, my mains pushswitch had an immediate and unfortunate accident – the protruding plastic actuator broke off. Hmmm.

However, I had another double-pole, single-throw mains power switch handy so I installed that instead. ***Don't change the mains switch unless you know exactly what you are doing with mains power. High voltages like these can kill you!***

Down to earth

Remember the earth lead that I mentioned earlier? Well, here's where it goes – under the nut on the screw that secures one of the front feet. What front feet? Oh well, I had some salvaged ones around the place…and their screws also attach the new snout to the underside of the power supply through the mounting lugs which are already there.

The openings at each end of the new snout were filled with plastic pieces cut to size and push-fitted into the openings – some glue will make sure that they stay in place. If the power supply is to be worked hard, drill some small holes in these pieces so that the fan can draw air in through the front vents in the power supply box. In my case there were enough small gaps around the case that the fan still flowed sufficient air.

In use

Depending on the PC power supply that you have selected, there may be a few tricks in actually using it. The one I had wasn't happy if you switched it on when a large load was applied – but it was as 'happy as Larry' if you applied that same load after it was turned on.

Others that I have heard of are the opposite – they need to have a small load happening before they'll start to work properly. So if you switch on and nothing much happens, keep these aspects in mind.

Rat It Before You Chuck It!

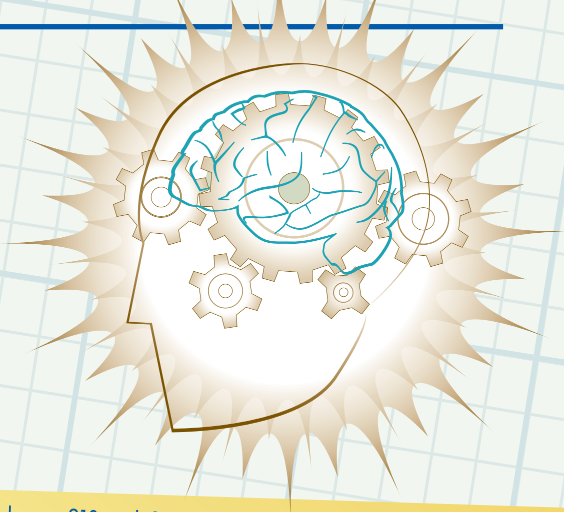
Whenever you throw away an old TV (or VCR or washing machine or dishwasher or printer) do you always think that surely there must be some good salvageable components inside? Well, this column is for you! (And it's also for people without a lot of dough.) Each month we'll use bits and pieces sourced from discards, sometimes in mini-projects and other times as an ideas smorgasbord.

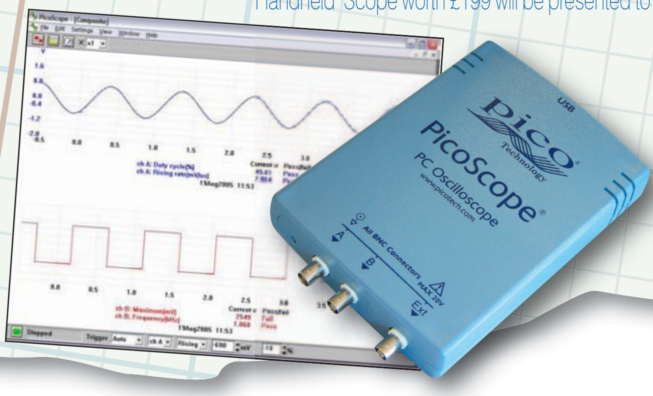
And you can contribute as well. If you have a use for specific parts which can easily be salvaged from goods commonly being thrown away, we'd love to hear from you. Perhaps you use the pressure switch from a washing machine to control a pump. Or maybe you have a use for the high-quality bearings from VCR heads. Or perhaps you've found how the guts of a cassette player can be easily turned into a metal detector. (Well, we made the last one up, but you get the idea…)

So, if you have some practical ideas, do write in and tell us!

Ingenuity Unlimited

Our regular round-up of readers' own circuits





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Your ideas could earn you some cash **and a prize** !

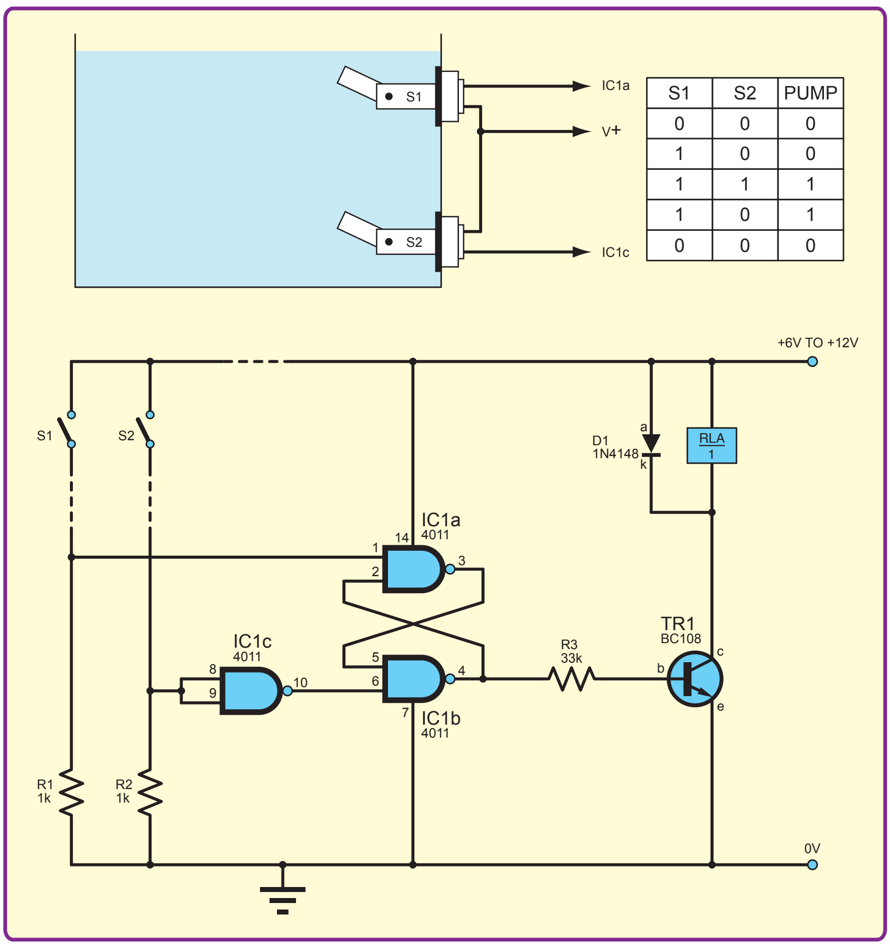
Water Pump Switch – *plant feeder*

THIS circuit was devised to control a pump in a garden watering scheme. A header tank is filled by a pump from rainwater storage butts. The tank is placed at the highest part of the garden, and provides a reserve of water, which is piped to various points around the garden. Two float switches in the tank enable it to be refilled automatically.

The circuit (Fig.1) uses a 4011 quad NAND gate to provide a latching switch. As the water level goes down, first S1 and then S2 close. This makes the latch of IC1a and IC1b go high, turning on transistor TR1, and hence also the relay and ultimately a water pump. When the full water level is reached again, S1 opens thereby resetting the latch and turning off the pump. A spare gate (IC1c) inverts the input to IC1b so that both switches are normally off and operate in the same way. The truth table is shown inset in Fig.1.

Construction of the circuit is straightforward, but it is *essential* that if a mains-powered pump is used, the relay *must* be mounted separately in its own box because of the mains voltage present. The switches are horizontal 'pivot-style' fluid switches in which a float pivots from the body of the switch. In the closed position, a magnet closes a sealed reed switch. When mounted, the switch can be rotated 180° to give either a normally-on or a normally-off position.

Tom Armitstead, Nr Haverhill, Suffolk



S1	S2	PUMP
0	0	0
1	0	0
1	1	1
1	0	1
0	0	0

Fig.1.Circuit diagram, header tank arrangement and truth table for the Water Pump Switch

Practically Speaking

Robert Penfold looks at the Techniques of Actually Doing it!

STRIPBOARD was probably invented to provide professional circuit designers with an easy way of building and testing prototype electronic gadgets. No doubt it did, and still does, fulfil this function very well, but stripboard probably had an even bigger impact in the world of electronic project building.

Unlike many forms of prototyping board, it provided a finished product that was reasonably neat, and perhaps of more importance, tough enough for use in finished units. It was an immediate success, as it provided a universal board that could be used to construct practically any project. Custom printed circuit boards now seem to be the standard method of construction for the electronics hobbyist, but at one time stripboard construction was the norm.

Although less popular than in the past, stripboard has advantages, and it is still particularly well suited to relatively simple projects where all you have is a circuit diagram to work from. Designing and building a custom printed circuit board is not too difficult, but it can be quite time consuming, even for a small board. It also requires a certain amount of additional equipment. With practice, it is possible to convert a small circuit diagram into a completed circuit on stripboard in a matter of minutes using nothing more than a soldering iron and the other basic tools of electronic project construction.

Perfect pitch

Like most good ideas, stripboard is basically a very simple product. It consists of a thin board made from a piece of insulating material and drilled with a matrix of small holes. With modern boards, the holes are 1mm in diameter and the pitch of the matrix is 2.54mm. This arrangement suits the vast majority of components, but there are obviously a few 'problem' types that cannot be fitted directly to the board.

Using adaptors or a bit of ingenuity it is possible to fit most types of component onto standard stripboard. With an adaptor for example, it is possible to use practically any surface-mount chip with stripboard.

Thin copper strips run along rows of holes on what is generally considered to be the underside of the board. This produces what is essentially a normal single-sided printed circuit board. Components are mounted on the plain (top) side of the board with the leadout wires being threaded through the holes, trimmed to length on the underside of the board, and then soldered to the copper strips.

Quick break

On the face of it, there is a major problem with stripboard in that each copper strip can only carry one set of connections. In practice, this limitation is overcome by adding breaks in the copper strips so that each section can carry a different set of interconnections.

Another obvious problem is that the copper strips only run horizontally and cannot carry connections up or down the board. Most stripboard layouts rely on a fair number of link-wires, which are largely required to compensate for this limitation.

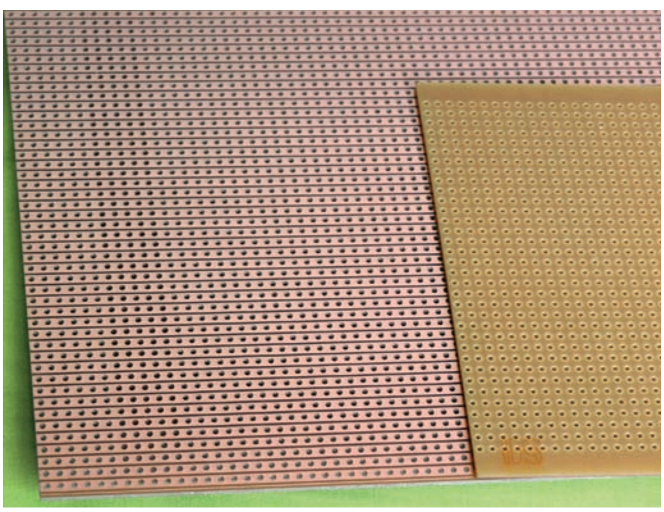
Using breaks in the copper strips and link wires it is possible to accommodate most circuits using stripboard, but the finished board is unlikely to be anything like as small and neat as a custom printed circuit board. It should do the job well enough for most purposes though.

There is another potential problem with stripboard, which is the capacitance between the copper strips. This can result in problems like signals being coupled from one strip to another producing unwanted feedback. To an extent, it is possible to alleviate this problem by adding breaks in some strips so that long unused sections are isolated from the circuit. Having an earthed copper strip between two problems strips can be used to largely remove any stray coupling from one to the other.

Obviously, the most important weapon against stray feedback is to design the board layout to, as far as possible, keep problem parts of the circuit well separated. There are some types of circuit where even a cleverly designed circuit layout is unlikely to provide satisfactory results, and stripboard is not really suitable for most radio frequency circuits for example.

Another slight drawback of stripboard is that it is not suitable for circuits that carry high currents. With a custom printed circuit board you can use a grade of board that has a thick copper layer intended for high current applications, and (or) the tracks can be made wider. As far as I am aware there is no high-current version of stripboard.

Most stripboard can handle currents of an amp or so without any problems arising, but it should not be used with higher currents. Sometimes it is possible to arrange things so that the main circuit running at relatively low currents is accommodated by the stripboard, with the high currents being carried by the hard-wiring to off-board components. In general though, stripboard is unsuitable for high current circuits.



Stripboard has a matrix of holes with copper strips on one side (underside) of the board. It is usually necessary to make breaks in some of the strips, either using a special tool, or a drill bit of about 5mm in diameter, which does the job quite well

Design rules

It is probably a mistake to design a stripboard layout using exactly the same set of design rules that would be applied when designing a custom printed circuit board. In particular, with a custom board it is normal for a standard lead spacing to be used for resistors, and for small resistors this would typically be 0.4 inches. Also, the resistors are often arranged in regimented rows.

This looks neat, but it does not really work too well when applied to stripboard. You tend to end up with large and over complex boards that have large numbers of link wires. With some types of component, such as integrated circuits and printed circuit mounting capacitors, you are often stuck with the natural lead or pin spacing of the component, and the use of link wires is then inevitable.

With axial lead components the lead spacing is elastic. It makes sense to exploit this flexibility, using it to partially compensate for the restrictions imposed by the stripboard.

On customised boards, the components are normally fitted straight up and down the board, or from side-to-side, but not at odd angles. While it is probably best to largely do things the same way with stripboard, if one or two components fit into the layout more easily at an angle, then I would ‘go with the flow’ and fit them in this fashion. Axial components can be mounted vertically in order to use a very small lead spacing, but it is best to keep this type of thing to a minimum. This method of mounting components is physically weak and any slight knock to a component can easily damage the board.

Making a start

With some circuits, it is possible for the stripboard layout to quite closely follow the layout of the circuit diagram. Unfortunately, with many real-world circuit diagrams there are large differences between the diagram and the physical world, but the circuit should at least provide a rough guide when designing the layout of a stripboard, and where appropriate, it can act as a more exact guide. It is probably best to start with some simple designs. A few designs can be drawn up purely as exercises if there are no very simple designs you wish to construct.

For the basis of this example, the simple Wien audio oscillator design of Fig.1 will be used. Although very simple, this circuit does pose a few problems, with a three-way two-pole switch and an awkward component in the form of torch bulb LP1.

There are no doubt numerous approaches to designing stripboards, but with a circuit such as this I always start by deciding on the height of the board. Two strips are required for the power rails, and four more are needed to accommodate the 8-pin DIL integrated circuit (IC1). A number of additional strips will be needed for the mid-rail bias voltage generated by resistors R1 and R2, the range capacitors (C3 to C8), the negative feedback components, and so one.

As some of the strips can be used to carry more than one connection, it is not necessary to work on the basis of one strip per set of connections. I eventually settled on eight additional strips, plus the six essential ones specified previously. Of course, you are not bound by your initial estimate, and a quick redesign of the board can be used if it becomes apparent that the selected figure is impractically small or far larger than is really required.

Board mounting

Unless the board will be mounted using guide rails, it will be necessary to have some additional strips for the mounting holes. A couple of mounting holes on one side are adequate with small and light boards, and are all I included here. Three additional strips were therefore added to the height of the board to provide space for these. With larger boards, a minimum of something like a mounting hole at each corner will be required, and extra strips then have to be included above and below the main part of the board. Most plastic standoffs do not work well with stripboard as they do not clip into the board reliably. It is advisable to use either mounting bolts and spacers, or standoffs of a type that are bolted to the board.

Stripboard is often made from a material that is quite brittle, and the matrix of small holes further reduces its strength. Make sure the mounting holes in the case are positioned to accurately match those in the board, or the board might buckle and crack when it is fixed in place. Also, be very careful when cutting stripboard down to the required size.

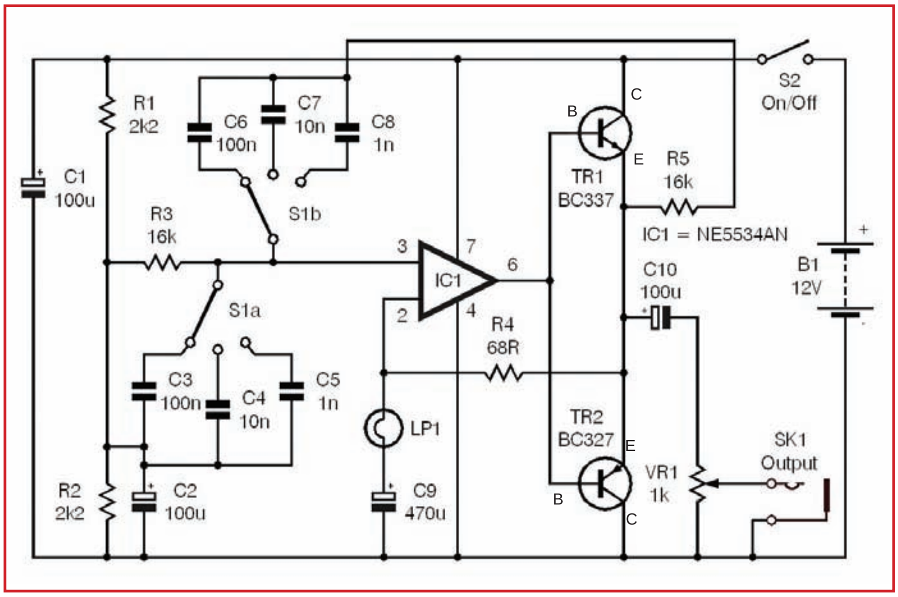


Fig.1. Although it is not entirely ‘plain sailing’, a simple circuit such as this Wien oscillator is easily turned into a working circuit built on stripboard.

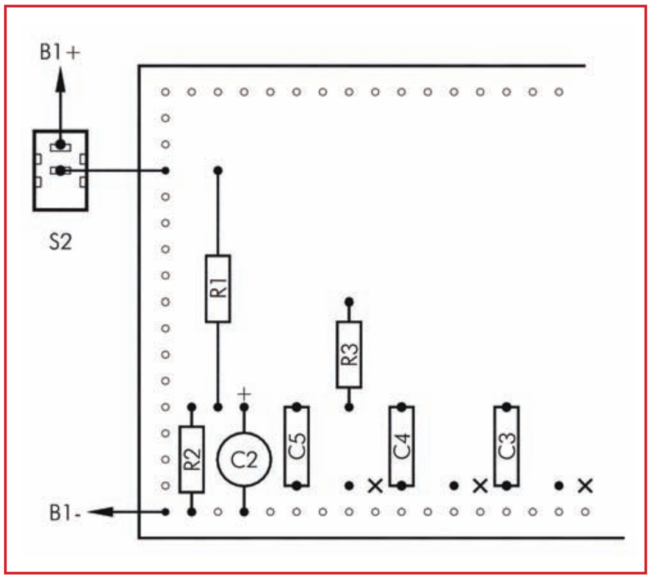


Fig.2. The early stages of the design. It is preferable for the connections to off-board components to be positioned near the edge of the board. Breaks in the underside copper strip are indicated by an ‘X’. The three dots are the solder pins

Lateral thinking

Having settled on a height for the board, there is no need to worry about the width. It can be allowed to grow horizontally as far as necessary. The obvious starting point for the design is to add the on/off switch (S2) and the battery (B1). Unless there is good reason to do otherwise, the bottom strip is used to take the 0V supply and the top strip (ignoring any extra strips to accommodate the mounting holes) is used for the positive supply. Next, I added R1, R2 and C2, which provide a mid-supply bias voltage. Three of the frequency selection capacitors (C3 to C5) connect to this mid-supply voltage, so I added them next, together with solder pins for the connections to the off-board frequency selection switch S1 – see Fig.2.

Resistor R3 also connects to this bias voltage, and it was added at this stage. This resistor connects to pin 3 of IC1, so in order to add this component it is necessary to decide on the vertical positioning of IC1.

The original intention was to have it placed at the mid-point, with five strips above and five beneath it. However, I decided to move it up a couple of strips to take it away from what was likely to become a rather congested lower section of the board. The design at this stage is shown in Fig.2.

It is considered good practice to have connections to the off-board components near an edge of the board, which means that with stripboard the bottom two or three strips will be used for most connections of this type. In this case, the second strip from the bottom is used for the connections to C3 to C5, which are printed circuit mounting components that all have the same pitch. This has necessitated breaks in the copper strips, which have been marked using crosses.

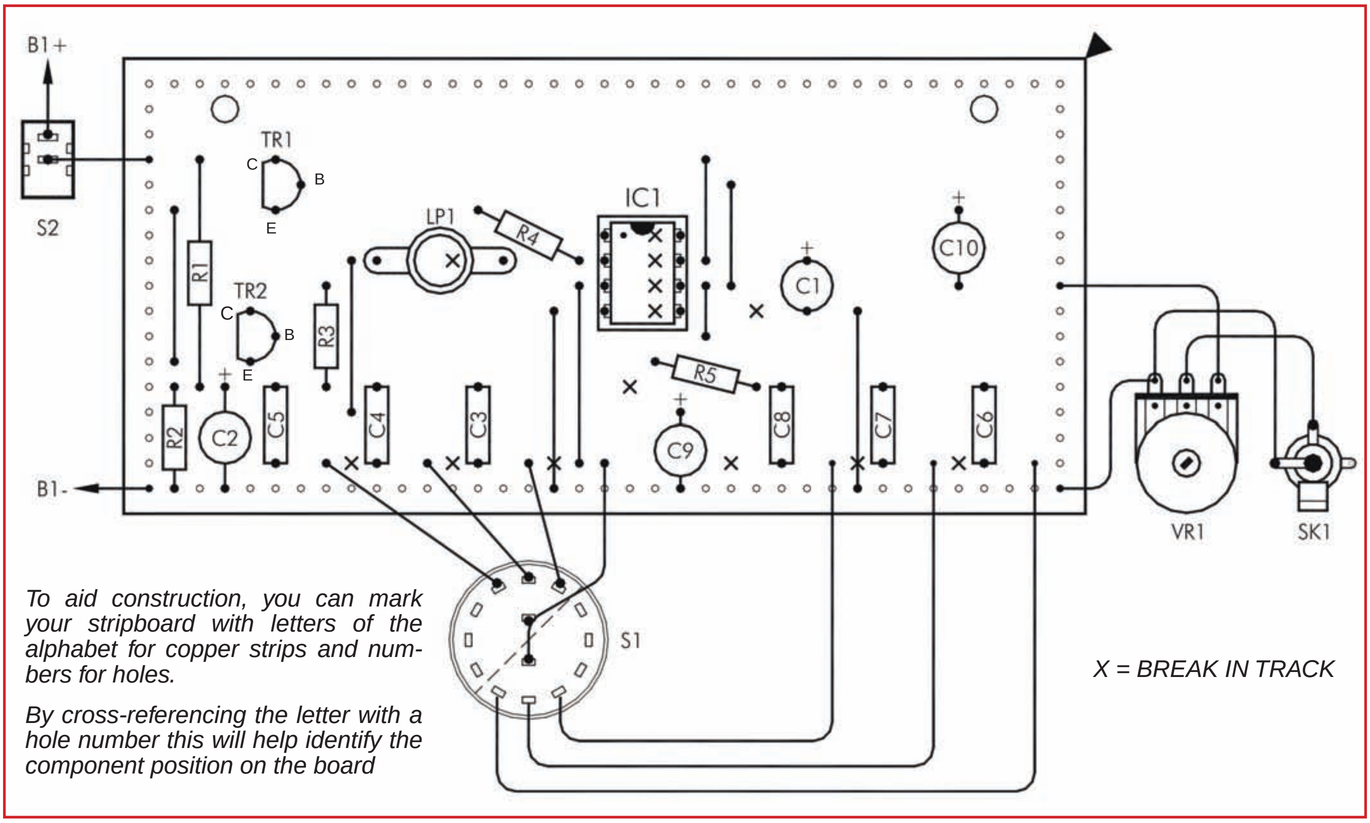


Fig.3. The finished design ready for checking. It is usually possible to make an initial layout neater with a little editing, but try not to introduce errors into a working design. (Note: there is a missing break in a track! – see text)

Referring to Fig.3, IC1 was added to the right of C3 to C5, and frequency selection capacitors C6 to C8 to the right of this. Link wires were added to connect the supply lines to the appropriate pins of IC1, and the connection from pin 3 of IC1 to the poles of S1 was added. From there on it was a matter of adding the remaining components into any convenient gaps on the board until the finished design was produced.

LP1 represented a minor problem because the only available holders for a torch bulb were not directly compatible with stripboard, or any other type of printed circuit board come to that. However, a holder having solder tags was available, and anything of this type can usually be connected to a circuit board via solder pins. This ploy worked well here.

To complete the lower arm of the negative feedback loop, capacitor C9 was added in a vacant area beneath IC1, and a link wire was added to connect it to LP1. The other arm (R4) cannot be added until the positions of transistors TR1 and TR2 have been decided. The obvious place for TR1 is with its collector (C) on the positive supply rail and the base (B) and emitter (E) terminals on the two strips beneath this. There is a lot of empty space in the upper part of the board, so the exact horizontal positioning is unimportant.

In a similar vein, TR2 could fit onto the bottom three strips, but this part of the board is quite crowded. I therefore connected its collector to the strip that carries the 0V supply to IC1, with the base and emitter going to the two strips beneath this. A link wire (to the left of R1) is then needed to connect the emitters of TR1 and TR2, and R4 can then be added between the two appropriate copper strips.

Missing links

At this stage, the circuit is largely in place, and it is just a matter of adding the missing link wires and components. The bases of TR1 and TR2 must be connected to the output of IC1 for example, and R5 must be added. It is then a matter of checking the design for errors, and in this case I have omitted a break in the copper strip between pin 6 of IC1 and the negative lead of C10. In most cases it is possible to adjust the layout to make it neater, but try to avoid the classic mistake of turning a rough but working layout into one that is neat but full of mistakes!

Most projects have more than one stage, but it is then a matter of taking things one stage at a time, making sure that the connections for one stage are properly isolated from the next stage, and that any links from one to the next are included. With some circuits it can be useful to set aside some extra strips near the top of the board specifically for the connections between stages.

With some logic circuits the approach of working along the board from left to right does not work too well. When busses and numerous other lines have to run here, there, and everywhere, it can be better to take a more vertical approach to the layout. Unfortunately, there is a limit to how far you can take this approach, because stripboard is not available in sizes more than about 50 or 60 strips high.

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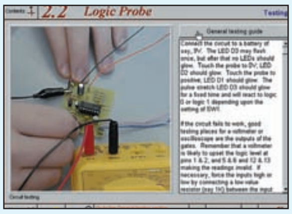
ELECTRONICS CD-ROMS

ELECTRONICS PROJECTS

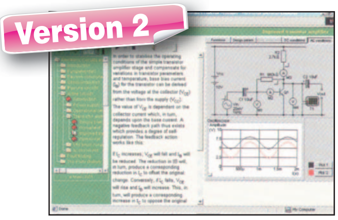


Logic Probe testing

Electronic Projects is split into two main sections: **Building Electronic Projects** contains comprehensive information about the components, tools and techniques used in developing projects from initial concept through to final circuit board production. Extensive use is made of video presentations showing soldering and construction techniques. The second section contains a set of ten projects for students to build, ranging from simple sensor circuits through to power amplifiers. A shareware version of Matrix's CADPACK **schematic capture, circuit simulation** and **p.c.b. design** software is included.

The projects on the CD-ROM are: Logic Probe; Light, Heat and Moisture Sensor; NE555 Timer; Egg Timer; Dice Machine; Bike Alarm; Stereo Mixer; Power Amplifier; Sound Activated Switch; Reaction Tester. Full parts lists, schematics and p.c.b. layouts are included on the CD-ROM.

ELECTRONIC CIRCUITS & COMPONENTS V2.0

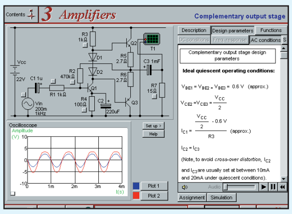


Circuit simulation screen

Electronics Circuits & Components V2.0 provides an introduction to the principles and application of the most common types of electronic components and shows how they are used to form complete circuits. The virtual laboratories, worked examples and pre-designed circuits allow students to learn, experiment and check their understanding. Version 2 has been considerably expanded in almost every area following a review of major syllabuses (GCSE, GNVQ, A level and HNC). It also contains both European and American circuit symbols. Sections include: ***Fundamentals***: units and multiples, electricity, electric circuits, alternating circuits. ***Passive Components***: resistors, capacitors, inductors, transformers. ***Semiconductors***: diodes, transistors, op amps, logic gates. ***Passive Circuits. Active Circuits***. *The Parts Gallery* will help students to recognise common electronic components and their corresponding symbols in circuit diagrams.

Included in the Institutional Versions are multiple choice questions, exam style questions, fault finding virtual laboratories and investigations/worksheets.

ANALOGUE ELECTRONICS

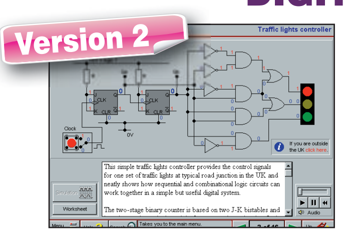


Complimentary output stage

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.

Sections on the CD-ROM include: ***Fundamentals*** – Analogue Signals (5 sections),Transistors (4 sections), Waveshaping Circuits (6 sections). ***Op Amps*** – 17 sections covering everything from Symbols and Signal Connections to Differentiators. ***Amplifiers*** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). ***Filters*** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). ***Oscillators*** – 6 sections from Positive Feedback to Crystal Oscillators. ***Systems*** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

DIGITAL ELECTRONICS V2.0

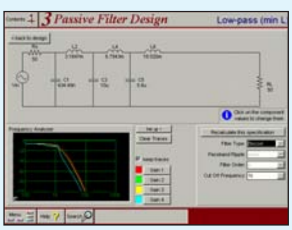


Virtual laboratory - Traffic Lights

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (above), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.

Covers binary and hexadecimal numbering systems, ASCII, basic logic gates, monostable action and circuits, and bistables – including JK and D-type flip-flops. Multiple gate circuits, equivalent logic functions and specialised logic functions. Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers. A/D and D/A converters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units. Sections on Boolean Logic and Venn diagrams, displays and chip types have been expanded in Version 2 and new sections include shift registers, digital fault finding, programmable logic controllers, and microcontrollers and microprocessors. The Institutional versions now also include several types of assessment for supervisors, including worksheets, multiple choice tests, fault finding exercises and examination questions.

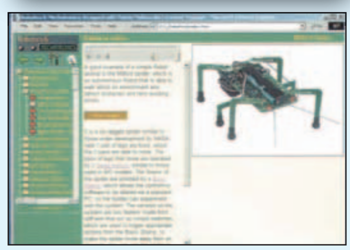
ANALOGUE FILTERS



Filter synthesis

Analogue Filters is a complete course in designing active and passive filters that makes use of highly interactive virtual laboratories and simulations to explain how filters are designed. It is split into five chapters: **Revision** which provides underpinning knowledge required for those who need to design filters. **Filter Basics** which is a course in terminology and filter characterization, important classes of filter, filter order, filter impedance and impedance matching, and effects of different filter types. **Advanced Theory** which covers the use of filter tables, mathematics behind filter design, and an explanation of the design of active filters. **Passive Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev ladder filters. **Active Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev op.amp filters. This CD-ROM is being discontinued, **only the Hobbyist/Student version is now available**.

ROBOTICS & MECHATRONICS



Case study of the Milford Instruments Spider

Robotics and Mechatronics is designed to enable hobbyists/students with little previous experience of electronics to design and build electromechanical systems. The CD-ROM deals with all aspects of robotics from the control systems used, the transducers available, motors/actuators and the circuits to drive them. Case study material (including the NASA Mars Rover, the Milford Spider and the Furby) is used to show how practical robotic systems are designed. The result is a highly stimulating resource that will make learning, and building robotics and mechatronic systems easier. The Institutional versions have additional worksheets and multiple choice questions.

- Interactive Virtual Laboratories
- Little previous knowledge required
- Mathematics is kept to a minimum and all calculations are explained
- Clear circuit simulations

PRICES

Prices for each of the CD-ROMs above are:

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Hobbyist/Student	**£45**	**inc VAT**
Institutional (Schools/HE/FE/Industry)	**£99**	**plus VAT**
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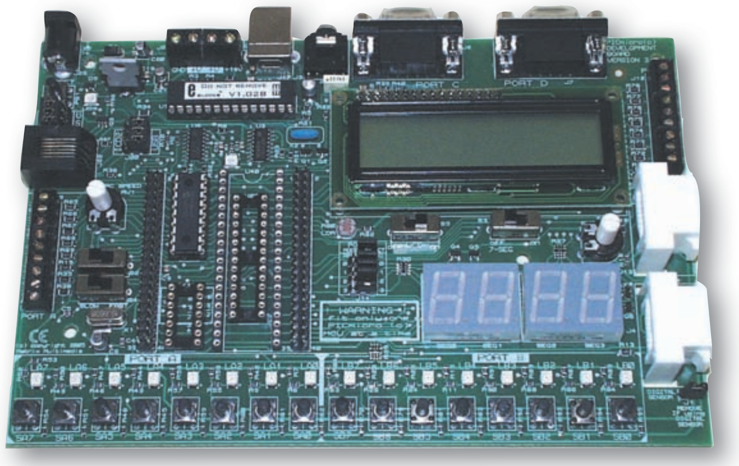

£158 including VAT and postage, supplied with USB cable and programming software

SOFTWARE

ASSEMBLY FOR PICmicro V3

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

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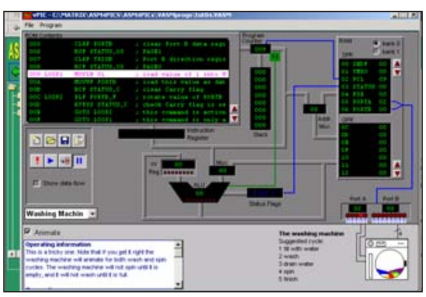

'C' FOR 16 Series PICmicro Version 4

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD-ROM contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

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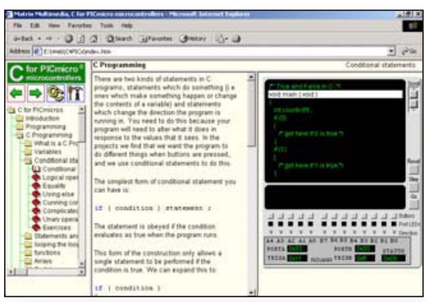

Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V4

Flowcode is a very high level language programming system based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

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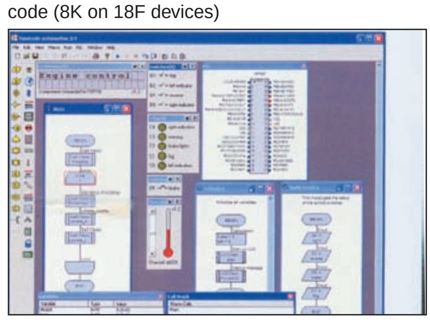
- Full on-screen simulation allows debugging and speeds up the development process.
- Facilitates learning via a full suite of demonstration tutorials
- Produces ASM code for a range of 18, 28 and 40-pin devices
- 16-bit arithmetic strings and string manipulation
- Pulse width modulation
- I2C.

New features of Version 4 include panel creator, in circuit debug, virtual networks, C code customisation, floating point and new components. The Hobbyist/Student version is limited to 4K of code (8K on 18F devices)



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***Flowcode V3** (Hobbyist/Student) – For details on Flowcode, see the previous page.*

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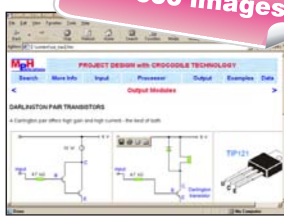

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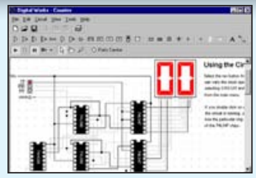
DIGITAL WORKS 3.0



Counter project

Digital Works Version 3.0 is a graphical design tool that enables you to construct digital logic circuits and analyze their behaviour. It is so simple to use that it will take you less than 10 minutes to make your first digital design. It is so powerful that you will never outgrow its capability ● Software for simulating digital logic circuits ● Create your own macros – highly scalable ● Create your own circuits, components, and i.c.s ● Easy-to-use digital interface ● Animation brings circuits to life ● Vast library of logic macros and 74 series i.c.s with data sheets ● Powerful tool for designing and learning.

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Alan Winstanley

Hitting a tweet spot

Broadband and mobile access now beams the Internet straight into the palm of our hands, delivering an endless array of websites, e-commerce, blogs, webcams and streaming TV and radio to our laptops and iPhones. I'm listening to *Svenska Favoriter Musik* online through my Pure Internet radio, as I type. Peer-to-peer (P2P) and social networks have brought together legions of users from every corner of the globe: the Internet was previously just a silo of information, but social networking is now *de rigeur*, and static websites and forums are so yesterday!

The Internet has in turn been the graveyard of many a venture that has crashed and burned. Many fashionable new ideas peak naturally in their popularity (eg Friends Reunited) before being shelved by a userbase having an insatiable appetite for something new. Some ideas hit a sweet spot at the right time and stick with us, and one such fad that shows no sign of going away is Twitter, a name that pops up in regular usage almost as much as Google, so in this month's *Net Work* I'll outline the rudimentary essentials of Twitter.

The Twitter website at **www.twitter.com** is a free gift to a texting generation that craves effortless immediacy and instant gratification, because it simply involves broadcasting a text message of a maximum of 140 characters. These messages, or 'tweets', were originally intended as a running commentary of what the 'tweeter' was doing at that time, but they have evolved somewhat: Twitter users often broadcast snippets of news about themselves or others, or they send a quick 'heads up' radar-blip of a message to share with anyone who might be interested.

Tweet updates are destined for friends and contacts (followers) who have opted to receive them in their own Twitter feeds, although you can generate public tweets if you want. Rather poorly in my view, Twitter makes your posts public by default, unless you deliberately make them 'private' in your settings. In turn, you can subscribe to or follow other Twitter users. What's more, you can re-transmit tweets that you receive, to other users (re-tweeting), also called an RT. You can create tweets either by logging into **www.twitter.com**, or you can post tweets via other routes (eg Facebook – but that's another story).

When you choose to follow other users, their tweets appear in your own Twitter homepage as a running timeline, with the latest tweets received appearing first. You can create and organise timelines using 'Lists', then add your choice users or businesses to various lists.

Trivial pursuit

Something we see on our own *Chat Zone* forum (**www.chatzones.co.uk**) is an '@reply' when follow-up posts are addressed mainly to an individual user rather than the group as a whole. In the 'tweetosphere', a reply to a tweet can be addressed to an individual user using an @reply. It appears in the public tweets and also in the individual's 'Replies' section in their own homepage.

Apart from sending and receiving tweets in a broadcast-fashion, personal tweets can be sent to an individual user – Twitter calls this 'direct messaging' or DM. This is slightly different to an @reply and there are various ways to do this, but you can only send a DM to someone who is following you. There are more options available when you are using Twitter on your mobile phone.

Other options include the insertion of 'hashtags' into your message, such as #PICmicro – this shortcut is merely a way of creating a searchable keyword that allows others to find your post. Online services such as **http://hashtags.org** provide an analysis of keyword popularity, for those wishing to track a particular trend. Such is the hunger in some sectors to gain market intelligence from tweets or manage their own PR that services like Cotweet (**www.cotweet.com**) help businesses to track keywords or, for example, engage with disgruntled customers who are tweeting about a shoddy service. How gratifying it must be, I suppose, to tweet about a particularly bad buy or poor service and then a few moments later receive a reply from a customer services manager promising to remedy it.

In the event that employees talk out of turn and bad-mouth their employer on Twitter or other social networks, Social Sentry by Teneros (**www.teneros.com**) can help bosses keep track of what their workers are up to. It promises to 'provide granular and real-time tracking (of employee activity) to eliminate significant corporate risks.'

I mentioned earlier how new online trends invariably plateau and tail off, either running out of cash, or maybe because something else comes along to replace a technology showing signs of going out of fashion. It is hard to foretell how Twitter can evolve beyond its 140 character restrictions; maybe it will become a staple killer-application for a smartphone or iPhone, or maybe people will just tire of it.

Industry and commerce has quickly recognised Twitter's potential value, as it sought to catch the tide of social networking. For example, NASA has its own Twitter feed at **www.twitter.com/nasa**, which has 466,000 followers and it appears in Lists owned by 20,500 users. Our own feed is at **www.twitter.com/epemag**.

Make a start

Hopefully, this month's *Net Work* will point readers in the right direction to getting started with Twitter. There is an enormous amount of online tutorials, hints and FAQs and a quick Google search is likely to fill in any gaps, and there is, of course, Twitter's own online Help. The next step is to visit **www.twitter.com** and sign up, then go to Settings and configure your options. Note especially the tick-box to 'Protect My Tweets', which prevents unwanted users from following you. Via the 'Mobile' tab in Settings, you can configure using Twitter from your mobile phone. You can then try adding our own Twitter feed – if you're an *EPE* Online subscriber, search for 'epemag' to receive up-to-date news about the latest issue of *EPE* Online.

Last, this month, a brief announcement of a new independent website created by the author to support the *EPE* reader and hobby electronics in general – **www.epemag.net** is a rolling project with more new resources promised in coming months.

You can email the author at: **alan@epemag.demon.co.uk** or share your views with the Editor at: **editorial@epemag.wimborne.co.uk**

A typical Twitter feed – this one is from NASA at **www.twitter.com/nasa**

READOUT

Email: editorial@wimborne.co.uk

Matt Pulzer addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

All letters quoted here have previously been replied to directly

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An Atlas LCR Passive Component Analyser, kindly donated by Peak Electronic Design Ltd, will be awarded to the author of the Letter Of The Month. The Atlas LCR automatically measures inductance from 1mH to 10H, capacitance from 1pF to 10,000μF and resistance from 1Ω to 2MΩ with a basic accuracy of 1%. www.peakelec.co.uk

☆ LETTER OF THE MONTH ☆

Tell us what you'd like

Dear Editor

First, thank you for asking us for what we would like to see in *EPE*.

I have been taking the magazine on and off since the mid-70s in all its different forms, especially in the 80s and 90s, when ICs were the latest thing, and have built a number of the circuits published.

I have been a programmer and software designer for most of my life (specialising in human interfacing and ease-of-use issues) in Foxpro and Foxprow (the Windows version) and spent a lot of time soldering up leads in the early days of PCs. However, I don't have an electronics background and so have tended to borrow (I admit) bits of projects to get them to do other things. So for me, *Ingenuity Unlimited* has always been a real source of good ideas to try out.

From the letters page, it is clear that you have already some excellent suggestions for projects coming in, but could I add a few brief comments?

1. For me, there is too much PIC-related content. I do wonder whether using assembler in 2010 is really the most efficient way of doing things. Most of the PIC projects seem to be over-complicated and over-engineered.

For some people this is fine – the software is complete and ready to go, and once you've built the project, that's it. The downside is that there is little chance of tinkering with it and adding bits, unless you have a complete knowledge of the particular PIC, plus all the software needed to make it work.

I'm not knocking PICs *per se*, I can understand their popularity now that Windows no longer provides access to the outside world from the PC. But couldn't PICAXE or one of the other easy PIC families be pushed to develop a fresh alternative? It would give readers access to the development of their own ideas, which might in turn produce more projects. And a higher-level language would be a bit more user friendly!

2. Could we see projects using the SD memory that is now cheaply available, for making remote dataloggers etc. How about some test rigs for reading and writing to them? This could be quite a new area to open up.

3. Your 'trash-it' articles are wonderful – please keep them coming! Could someone also run up a simple IC driver for the little positioning stepper motor to be found inside the humble single disc drive? These are available for virtually nothing. I have rescued quite a number for projects, but I'm still hunting for an interface.

4. My current projects are a repeating weathervane, which has a miniature stepper-driven version to hang on the wall. And a radio-controlled clock, which has analogue day, date and month read outs – useful for the elderly, who find liquid crystal displays almost impossible.

I enjoy the general and news articles, and find these valuable. The down under input is great and gives a fresh look to the whole publication. It is nice to see that Barry Fox is still contributing to the magazine – he is always good value, and Thomas Scarborough always has interesting ideas.

Thank you for asking for our opinions. The magazine has been through many different versions, but I hope this one is around for a long time – it deserves to be!

All the best with the magazine

Tom Armitstead, via email

Thank you for the feedback Tom, as always much appreciated. It is difficult to get the balance right between PICs and other devices, or even just which PICs to choose. We regularly keep an eye open for what's new and relevant, and are grateful for readers' suggestions. The PICAXE certainly seems to be a popular device and I will explore it further.

You're right, SD memory is cheap and it might be time to look at some projects built around it. I'm glad you like the recycling articles; they are certainly a firm favourite of mine. Good luck with your current projects and thank you again for your comments.

Shiny plastic bag insulator conundrum

Dear Editor

I read with interest Godfrey Manning's letter to the editor in the June edition of *EPE*, especially the second half, where he talks about anti-static bags.

As a computer technician who has handled literally thousands of these bags, I too often pondered on how they work and have come to the conclusion that they must be conductive in order to safely carry out their task of protecting their static-sensitive contents. Ironically, most plastics are great insulators, yet if one rubs plastic with something like wool, they can charge up to thousands of volts, which could kill static-sensitive components. In fact, many of the traditionally non-conductive materials used to package electronic hardware (like the cardboard and plastic foam that computer motherboards come packed in) can generate huge amounts of static in the right circumstances, which is why the actual motherboard lives in an anti-static bag inside the box.

I originally started thinking about anti-static bags because often when pulling a new motherboard from its anti-static bag, I feel the hair on my arm stand up as the bag charges up. So why then, don't the contents get damaged?

As I understand it, the object is to channel (or 'wick') as much as possible of this potentially dangerous static electricity away from vulnerable components, and anti-static bags can only do this by being conductive, both inside and out. They use a combination of methods for protecting components. First, bags redistribute any electrical charge built up on them over a wider area and this helps minimise overall static charge, especially any that reaches the component inside. Second, the material the bag is made of discourages static from being stored on the bag's surface; any static charge accumulated quickly bleeds off into the atmosphere, much in the same way that static electricity that builds up on an aircraft's airframe as it flies through the air is

bled off into the atmosphere by (conductive) static wicks mounted on the trailing edges of the flying surfaces, which prevents people inside from being shocked should they touch anything metal, like modern aircraft toilet pans for example (ouch!).

The outside of many anti-static bags have patterns of conductive 'tracks' on them to facilitate this current flow, while the insides are smooth to prevent 'hot spots' forming, from which static could possibly discharge. Plus, should any static charge reach the component inside the bag, it is likely to be spread over any or all connections or pins touching the bag, some of which are earthed internally, which brings everything to relatively the same potential.

This is the same theory as the way conductive foam essentially joins all pins of a CMOS chip together, tying them all to a 'common ground' so any charge is applied equally to all pins at the same time. This helps prevents damage to the component, except in extreme static conditions, though in such circumstances the handler is likely to be zapped as well!

If this foam was made of something like polystyrene, (something not recommend for storing components unless covered in (conductive) tin-foil first) then it could kill the component as soon as it touched it because it could retain considerable charge. If, however, the foam is conductive, then it is likely any charge won't accumulate on it because, just like the bags, any electric potential would soon bleed off into the atmosphere.

That's my theory anyway. It does make some electrical sense, though I will happily re-evaluate my position should someone more knowledgeable than myself put forward a better explanation.

Thanks and keep up the excellent work.

Dave Thompson
Director, PC Anytime Limited
Christchurch, New Zealand

Dear Editor

I believe I can answer the 'shiny plastic bag insulator' conundrum.

The black bags and foam are conductive so as to protect the device from static by surrounding the device with a Faraday shield in the case of the bag, or shorting all the device's leads in the case of the foam. In the case of the clear plastic bag there is no shielding. Instead, the bag is merely 'antistatic', so it generates little or no static itself, unlike generic plastic bags. Often antistatic plastic will be a pink colour.

The best protection is a conductive bag or foam, but it is more expensive and less appealing.

By the way, I have worked for several years in 'quality and reliability' for the semiconductor industry, and have implemented ESD control programs in manufacturing and shipping areas.

Dan Koellen
Roseville, California USA, by email

Most helpful, thank you to both Dave and Dan. While these throries certainly make sense, is there any other opinion on the 'shiny plastic bag insulator' conundrum?

EPE solves communication problem!

Dear Editor

I found your article on *USB-to-Serial Conversion* in the Feb '10 issue of *EPE* really useful. The article appeared at just at the right time, because I was interested in trying an RS232 boot loader for a PIC (18F2550) microprocessor. With only USB ports on my PC, the FT232RL chip was ideal, and because it does not need the MAX 232 level converter that is normally used to connect a native RS232 port to a PIC microprocessor. I had no problems using FT232RL in this context.

The maximum communication speed I could achieve with Windows 7 was 57600 baud. This was half that claimed for a native serial RS232 port. For the project I used an FT232RL chip mounted on a breakout board by **sparkfun.com**. As supplied, the output level control, VCCIO, is set at 3.3V by a solder link. This link has to be removed before the board can be configured to give an RS232 signal with a 5V logic level.

Andrew Cunningham, by email

Glad to be of service! Nothing like the serendipity of having a problem solved in your favourite electronics magazine.

POV hard disk idea

Dear Editor

I am interested in building a POV (persistence of vision) display to show a clock. This means using a fast DC motor, an encoder for sensing the motor speed, a set of LEDs and the controller, which will be mounted on a bracket attached to the motor shaft.

One idea I have thought about is to make this project using a recycled, damaged hard disk. Although the hard disk should be scrap from a data storage point of view, it is important that the hard disk motor is still functional.

IF YOU HAVE A SUBJECT YOU WISH TO DISCUSS ON THIS PAGE PLEASE EMAIL US AT:

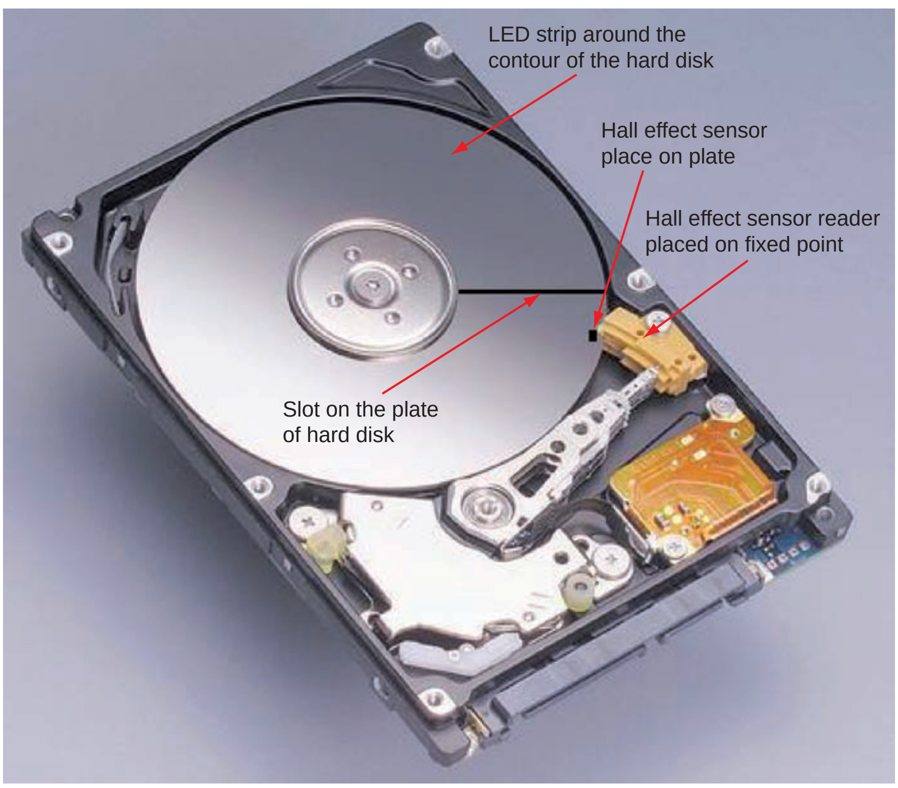
editorial@wimborne.co.uk

The hard disks incorporate a very fast motor, and an ideal mounting for the LED strip. The construction of the POV display on the hard-disk involves making a slot on the disk, placing a set of LEDs underneath the plate of the hard disk and positioning an encoder at the side of the hard disk. By making these three main adjustments, the only remaining step is the programming part of the microcontroller interface with the motor, sensor and LEDs.

Stephen Zahra, Malta, by email

A nice idea Stephen, hard disks are full of very high quality mechanical components and virtually free if they have stopped functioning. The only hitch I can see in your design is cutting the slot in the hard disk. Many of the platters are essentially sheets of glass, which is, of course, not an ideal material for slotting.

You might avoid this issue by using reflection instead of transmission, ie paint a matt black line on to the platter and detect reflection interrupts. You will also avoid straining the bearings by keeping the platter properly balanced. Do keep us abreast of any progress.



Max's Cool Beans

By Max The Magnificent

Retro iPod headphones

I don't know about you, but I tend to collect all sorts of electronic 'stuff', saying to myself 'I'm sure that this will come in handy one day,' and then forgetting all about it. In the not-so-distant past, for example, I was rooting around in my office when I ran across a box of old headphones I've acquired over the years. These are all from the late 1920s and early 1930s, and some of them are rather 'tasty', if you know what I mean.

Sad to relate, most of these little beauties simply don't work. And, even in the case of the ones that do, their connectors don't fit into any equipment I own. But they do look sooooo nice! When I started thinking about this, I realized that if I didn't get off my bottom and actually do something with them, they would sit in this box for decades to come until I decide to shrug off this mortal coil and head on to new adventures in the next plane of my existence. At that point, my family will doubtless say something like: 'Here's another box of Max's rubbish,' and throw my beautiful headphones in the trash. Bummer!

So I decided to play around a little. First I searched through my 'collection' until I found a really nice pair with black Bakelite ear pieces and a wire-frame headset (it's amazing how many different types of mechanical fittings the headphone designers of yesteryear came up with). Next, I wandered down to a local store and picked up a pair of cheap-and-cheerful iPod headphones (I think they were around £7).

When I returned to my office, I dismantled the iPod phones to get at their inner 'speakers'. I had originally planned on using old cables (well, modern equivalents – you can actually buy really nice cloth-wrapped cables from specialty stores – I have some somewhere in my office), but in the end it proved easier to use the cables that came with the iPod phones. I simply cut these cables about an inch from the iPod speakers, removed the inner contents from the old headphones, and replaced them with their iPod equivalents. Then I reassembled the antique phones and attached the rest of the iPod speaker cable to the backside of their earpieces.

The result sounds surprisingly good. Honestly, I personally think that these sound better than any of my 'real' iPod earpieces and/or headphones. And the big thing is that they look really, really cool.

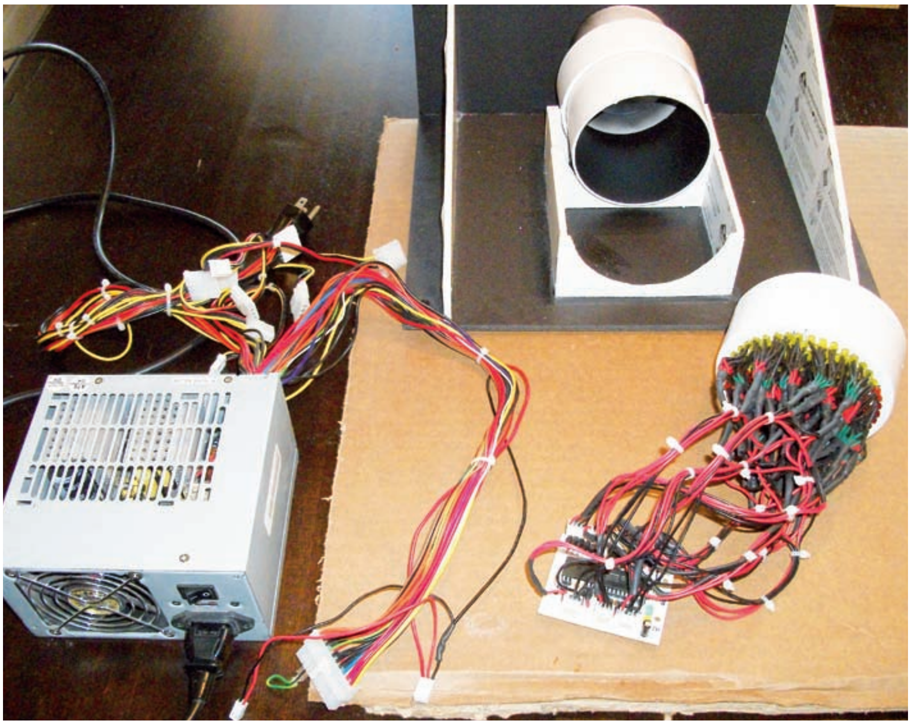
When was the last time someone commented on your iPod headphones? People comment on mine all of the time. When I showed my little beauties to a couple of my friends, for example, everyone started jumping up and down (it wasn't a pretty sight) saying that they want a pair of their own ... so I guess I know what I'll be doing for Christmas presents this year.

The beast

Do you recall my 'Man versus Woman Display-O-Meter' project? (See the Sept '09 issue for more details.) If not, just to bring you up to date, this is going to be a complicated beasty with lots of switches and knobs and meters (Oh My!) that sits in the corner humming along to itself, tempting you to press buttons and twiddle with things.

This is going to be implemented in a large antique radio cabinet. The front panel is going to be brass and the whole thing is going to be realized in a 'steampunk' style, which means that it would not look out of place in a Victorian setting. As part of this, I decided that it would be rather cool to have 'The Beast' look as though it was powered by a small, coal-fired furnace.

Max's 1930s 'retro' black Bakelite earpieces (headphones) and wire-frame headset in which he produced 21st century iPod phones – the result sounds surprisingly good!



The PC power supply is shown on the left. The back of the furnace with all of the LEDs connected to Joe Farr's PIC-based control board is on the right

In the fine tradition of 'overkill', I've spent an inordinate amount of time constructing this little scamp using 168 light-emitting diodes (LEDs). These are divided into three main groups – 56 red, 56 orange, and 56 yellow. In turn, each group of 56 is divided into eight sub-groups of seven LEDs. And each of the 24 sub-groups is controlled by its own pulse-width modulated (PWM) control signal. My old chum Joe Farr in the UK designed and built a small PIC-based control board to generate these PWM signals, but that's a tale for another day.

The point is, that I know that an individual LED doesn't draw very much current, so in the back of my mind I guess I thought that a lot of LEDs would not draw very much current. Being a careful man, however, before connecting everything together and powering it up, I first connected all of the LEDs to my regulated bench-top power supply and turned it on. The current meter immediately slammed over into the 'red zone'.

So I powered everything down and started thinking (it had to happen one day). As a 'back of the envelope' calculation, let's say that an individual LED draws 20mA; so five LEDs will draw 100mA; so 50 LEDs will draw 1A; so 150 LEDs will draw 3A... Phew! No wonder my poor little old power supply (which is rated at less than 2A maximum) is struggling.

Wow! A 30A 5V power supply for only £5!

OK, so I need a bigger power supply. I did a quick search on the web and found a variety of offerings ranging from £15 (which isn't bad) to ... let's just say much, much more. But I am a man who desires instant gratification. I really want to start playing with my furnace trying out different effects as soon as possible, so I decided to wander over to my local technology recycling centre, which is located only about half a mile from my office.

After a cheery greeting (they see a lot of me down there), I inquired as to the availability of a 5V, 5A power supply. No such luck, I'm afraid. Then one of the guys asked me exactly what I wanted it for. When I explained, he said 'Have you thought about using a PC power supply?' Well, I hadn't, but he pulled one off the shelf and showed it to me – this little beauty puts out a collection of reasonably well-regulated +5V, –5V, +12V, and –12V supplies. In the case of the +5V (which is what I want), it will max out at 30A, so it can easily handle my modest demands. (*See this month's* Recycle It! *for more info on salvaging old PC power supplies – Ed.*).

'How much?' I hear you cry. Would you believe only £5? As soon as I returned to my office I emailed Joe in the UK to tell him what I was up to (he likes to stay informed), and then I plugged my new power supply into the wall and clicked the power switch ... and nothing happened. Give me strength! I'm too young for all of this.

When I returned to my desk muttering and moaning, I found a response from Joe saying: 'Don't forget that there's a safety cutout on these things and you have to jumper a couple of wires to make it work.' Who would have thought? Fortunately, my office is in a building where a bunch of other guys make their own computers, so I wandered over to their bay and asked if they knew anything about this and they immediately responded: 'Oh yes, you have to jumper the green and black wires!' They even gave me a little jumper cable that was lying around. I plugged it in and my power supply leapt into life – hurray!

So the next step is to actually power up my 'furnace', which I intend to do as soon as I finish writing this column. Watch this space, and I shall report back further in a future article. Until next time, have a good one!

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The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last book page.

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NEW

Electronics Teach-In 3

FREE CD-ROM

The three sections of this book cover a very wide range of subjects that will interest everyone involved in electronics, from hobbyists and students to professionals. The first 80-odd pages of Teach-In 3 are dedicated to *Circuit Surgery*, the regular *EPE* clinic dealing with readers' queries on various circuit design and application problems – everything from voltage regulation to using SPICE circuit simulation software.

The second section – *Practically Speaking* – covers the practical aspects of electronics construction. Again, a whole range of subjects, from soldering to avoiding problems with static electricity and indentifying components, are covered.

Finally, our collection of *Ingenuity Unlimited* circuits provides over 40 different circuit designs submitted by the readers of *EPE*.

The free cover-mounted CD-ROM is the complete *Electronics Teach-In 1* book, which provides a broad-based introduction to electronics in PDF form, plus interactive quizzes to test your knowledge, TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial), together with simulations of the circuits in the Teach-In 1 series, plus Flowcode (a limited version) a high level programming system for PIC microcontrollers based on flowcharts.

The Teach-In 1 series covers everything from Electric Current through to Microprocessors and Microcontrollers and each part includes demonstration circuits to build on breadboards or to simulate on your PC. There is also a MW/LW Radio project in the series.

The contents of the book and Free CD-ROM have been reprinted from past issues of *EPE*.

160 pages+CD-ROM | **Order code ET3** | **£8.50**

ROBOTICS

INTRODUCING ROBOTICS WITH LEGO MINDSTORMS
Robert Penfold

Shows the reader how to build a variety of increasingly sophisticated computer controlled robots using the brilliant Lego Mindstorms Robotic Invention System (RIS). Initially covers fundamental building techniques and mechanics needed to construct strong and efficient robots using the various "click-together" components supplied in the basic RIS kit. Then explains in simple terms how the "brain" of the robot may be programmed on screen using a PC and "zapped" to the robot over an infra-red link. Also, shows how a more sophisticated Windows programming language such as Visual BASIC may be used to control the robots.

Detailed building and programming instructions provided, including numerous step-by-step photographs.

288 pages - large format | **Order code BP901** | **£14.99**

MORE ADVANCED ROBOTICS WITH LEGO MINDSTORMS – Robert Penfold

Shows the reader how to extend the capabilities of the brilliant Lego Mindstorms Robotic Invention System (RIS) by using lego's own accessories and some simple home constructed units. You will be able to build robots that can provide you with 'waiter service' when you clap your hands, perform tricks, 'see' and avoid objects by using 'bats radar', or accurately follow a line marked on the floor. Learn to use additional types of sensors including rotation, light, temperature, sound and ultrasonic and also explore the possibilities provided by using an additional (third) motor. For the less experienced, RCX code programs accompany most of the featured robots. However, the more adventurous reader is also shown how to write programs using Microsoft's VisualBASIC running with the ActiveX control (Spirit.OCX) that is provided with the RIS kit.

Detailed building instructions are provided for the featured robots, including numerous step-by-step photographs. The designs include rover vehicles, a virtual pet, a robot arm, an 'intelligent' sweet dispenser and a colour conscious robot that will try to grab objects of a specific colour.

198 pages | **Order code BP902** | **£14.99**

ANDROIDS, ROBOTS AND ANIMATRONS
Second Edition – John Iovine

Build your own working robot or android using both off-the-shelf and workshop constructed materials and devices. Computer control gives these robots and androids two types of artificial intelligence (an expert system and a neural network). A lifelike android hand can be built and programmed to function doing repetitive tasks. A fully animated robot or android can also be built and programmed to perform a wide variety of functions.

The contents include an Overview of State-of-the-Art Robots; Robotic Locomotion; Motors and Power Controllers; All Types of Sensors; Tilt; Bump; Road and Wall Detection; Light; Speech and Sound Recognition; Robotic Intelligence (Expert Type) Using a Single-Board Computer Programmed in BASIC; Robotic Intelligence (Neutral Type) Using Simple Neural Networks (Insect Intelligence); Making a Lifelike Android Hand; A Computer-Controlled Robotic Insect Programmed in BASIC; Telepresence Robots With Actual Arcade and Virtual Reality Applications; A Computer-Controlled Robotic Arm; Animated Robots and Androids; Real-World Robotic Applications.

224 pages | **Order code MGH1** | **£16.99**

RADIO

BASIC RADIO PRINCIPLES AND TECHNOLOGY
Ian Poole

Radio technology is becoming increasingly important in today's high technology society. There are the traditional uses of radio which include broadcasting and point to point radio as well as the new technologies of satellites and cellular phones. All of these developments mean there is a growing need for radio engineers at all levels.

Assuming a basic knowledge of electronics, this book provides an easy to understand grounding in the topic.

Chapters in the book: Radio Today, Yesterday, and Tomorrow; Radio Waves and Propagation; Capacitors, Inductors, and Filters; Modulation; Receivers; Transmitters; Antenna Systems; Broadcasting; Satellites; Personal Communications; Appendix – Basic Calculations.

263 pages | **Order code NE30** | **£28.99**

PROJECTS FOR RADIO AMATEURS AND S.W.L.S.
R. A. Penfold

This book describes a number of electronic circuits, most of which are quite simple, which can be used to enhance the performance of most short wave radio systems.

The circuits covered include: An aerial tuning unit; A simple active aerial; An add-on b.f.o. for portable sets; A wavetrap to combat signals on spurious responses; An audio notch filter; A parametric equaliser; C.W. and S.S.B. audio filters; Simple noise limiters; A speech processor; A volume expander.

Other useful circuits include a crystal oscillator, and RTTY/C.W. tone decoder, and a RTTY serial to parallel converter. A full range of interesting and useful circuits for short wave enthusiasts.

92 pages | **Order code BP304** | **£4.45**

AN INTRODUCTION TO AMATEUR RADIO
I. D. Poole

Amateur radio is a unique and fascinating hobby which has attracted thousands of people since it began at the turn of the last century. This book gives the newcomer a comprehensive and easy to understand guide through the subject so that the reader can gain the most from the hobby. It then remains an essential reference volume to be used time and again. Topics covered include the basic aspects of the hobby, such as operating procedures, jargon and setting up a station. Technical topics covered include propagation, receivers, transmitters and aerials etc.

150 pages | **Order code BP257** | **£5.49**

COMPUTERS AND COMPUTING

ELECTRONICS TEACH-IN 2
USING PIC MICROCONTROLLERS A PRACTICAL INTRODUCTION

FREE CD-ROM

This *Teach-In* series of articles was originally published in *EPE* in 2008 and, following demand from readers, has now been collected together in the *Electronics Teach-In 2* book.

The series is aimed at those using PIC microcontrollers for the first time. Each part of the series includes breadboard layouts to aid understanding and a simple programmer project is provided.

Also included are 29 *PIC N' Mix* articles, also republished from *EPE*. These provide a host of practical programming and interfacing information, mainly for those that have already got to grips with using PIC microcontrollers.

An extra four part beginners guide to using the C programing language for PIC microcontrollers is also included.

The free cover-mounted CD-ROM contains all of the software for the *Teach-In 2* series and *PIC N' Mix* articles in this book, plus a range of items from Microchip – the manufacturers of the PIC microcontrollers. The material has been compiled by Wimborne Publishing Ltd. with the assistance of Microchip Technology Inc.

The Microchip items are: MPLAB Integrated Development Environment V8.20; Microchip Advance Parts Selector V2.32; Treelink; Motor Control Solutions; 16-bit Embedded Solutions; 16-bit Tool Solutions; Human Interface Solutions; 8-bit PIC Microcontrollers; PIC24 Micrcontrollers; PIC32 Microcontroller Family with USB On-The-Go; dsPIC Digital Signal Controllers.

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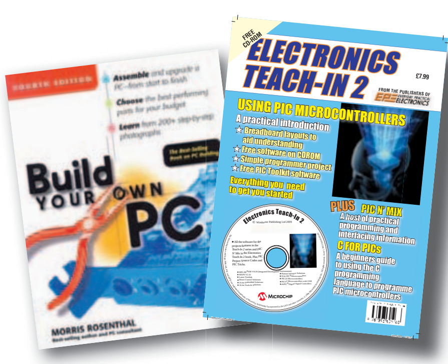

BUILD YOUR OWN PC – Fourth Edition
Morris Rosenthal

More and more people are building their own PCs. They get more value for their money, they create exactly the machine they want, and the work is highly satisfying and actually fun. That is, if they have a unique beginner's guide like this one, which visually demonstrates how to construct a computer from start to finish.

Through 150 crisp photographs and clear but minimal text, readers will confidently absorb the concepts of computer building. The extra-big format makes it easy to see what's going on in the pictures. The author goes 'under the hood' and shows step-by-step how to create a Pentium 4 computer or an Athlon 64 or Athlon 64FX, covering: What first-time builders need to know; How to select and purchase parts; How to assemble the PC; How to install Windows XP. The few existing books on this subject, although outdated, are in steady demand. This one delivers the expertise and new technology that fledgling computer builders are looking for.

224 pages - large format | **Order code MGH2** | **£16.99**

PROGRAMMING 16-BIT PIC MICROCONTROLLERS IN C – LEARNING TO FLY THE PIC24 Lucio Di Jasio (Application Segments Manager, Microchip, USA)

A Microchip insider tells all. Focuses on examples and exercises that show how to solve common, real-world design problems quickly. Includes handy checklists to help readers perform the most common programming and debugging tasks. FREE CD-ROM includes source code in C, the Microchip C30 compliler, and MPLAB SIM software, so that readers gain practical, hands-on programming experience.

Until recently, PICs didn't have the speed and memory necessary for use in designs such as video- and audio-enabled devices. All that changed with the introduction of the 16-bit PIC family, the PIC24. This new guide teaches readers everything they need to know about the architecture of these chips, how to program them, how to test them and how to debug them. Lucio's common-sense, practical, hands-on approach starts out with basic functions and guides the reader step-by-step through even the most sophisticated programming scenarios.

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Ian Waugh

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R. A. Penfold

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For details see the UK shop on our web site at www.epemag.com or contact us for a list of *Radio Bygones* books.

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This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including the following topics:

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The subjects covered include:- Magnetic field detector, Basic Hall effect compass, Hall effect audio isolator, Voice scrambler/descrambler, Bat detector, Bat style echo location, Noise cancelling, LED stroboscope, Infra-red "torch", Electronic breeze detector, Class D power amplifier, Strain gauge amplifier, Super hearing aid.

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The projects include:- Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.

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GETTING THE MOST FROM YOUR MULTIMETER
R. A. Penfold

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